Aalto University
School of Business

THE EDUCATION-HEALTH GRADIENT: ATTEMPTING TO ESTABLISH A CAUSAL RELATIONSHIP FROM SCHOOLING TO HEALTH

A literature review of theoretical and empirical studies that explore the relationship between education and health

Master's Thesis
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Master's Programme in Economics
Spring 2021

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Abstract of master's thesis

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Title of thesis The Education-Health Gradient: Attempting to Establish a Causal Relationship from Schooling to Health

Degree Master's Degree

Degree programme Economics

Thesis advisor(s) Tuomas Pekkarinen

Year of approval 2021 **Number of pages** 61 **Language** English

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Abstract

Within the social sciences and economics literature, there has been a well-established correlation between education and health as key components of human capital. This correlation has been shown to hold across a variety of contexts including geography, education level, time period in history, gender, and race. There exists great interest in establishing a robust causal relationship, especially in the direction of education on health, as societies face the need to develop new public policies that address the growing health burdens that exist. For example, structural factors in Europe such as the ageing population have led to the need to be more efficient with resources in the healthcare sector. The ageing population has led to an increase in the demand for healthcare services while there are less working age people who can help finance the burden. Many governments have considered education-based reforms with the reasoning that better education outcomes in a population would lead to better overall health outcomes. However, a causal link from education to health must be established to justify implementing such policy approaches.

I address the question of how economists have attempted to prove a causal link from education to health by performing a literature review on both theoretical and empirical approaches to examining the health-education relationship. The theoretical literature on the relationship is grounded in Grossman's health capital model, which identifies some of the unique factors that makes health different from other forms of human capital. Unlike other forms of capital, health provides direct utility while also having the possibility of being an investment commodity. Grossman argues that health should be viewed as a fundamental object of choice rather than some bundle of goods and services. This argument becomes apparent especially in the case where health is viewed as an investment. By building off Becker's (1965) seminal work on the theory of time allocation, Grossman identifies that health can be used to determine the total amount of time that can be spent on labor or producing nonmarket commodities. Furthermore, health is unique in that health affects the number of periods or total duration in which people can be productive.

Ultimately, the theoretical literature reveals two key approaches through which education could cause better health: the productive efficiency approach and the allocative efficiency approach. The productive efficiency approach posits that education increases the amount of health that an individual is capable of producing. On the other hand, the allocative efficiency approach argues that education affects health by improving the individual's understanding of their health function. Individuals would thus allocate their resources more efficiently or effectively depending on their education levels.

By examining the empirical literature on the productive and allocative efficiency approaches to the education-health relationship, it is possible to make a number of claims to suggest how exactly education would affect health. To empirically verify the productive efficiency approach, a number of retrospective survey analyses have been conducted where various subjective health indicators are used to provide an aggregate indicator for the total health stock. A study by Wagstaff (1986) using the 1976 Danish Health Survey as well as a study by Erbsland et al (1995) using the 1986 West German socioeconomic panel both suggest that schooling has a significant effect in two specific ways: better educated people consume more health and use less physician visits.

For the allocative efficiency approach, promising studies have looked at the uptake of new information or technologies as a proxy for how people, depending on their education levels, respond to choices regarding their health. For example, studies by De Walque (2010) and Farrell and Fuchs (1982) involving smoking information campaigns have shown there is indeed a positive relationship between education and the overall prevalence of smoking which has a clear link to health outcomes. Another method to empirically test the allocative efficiency approach has been to study the relationship between education and the uptake of new medical technologies that would improve health outcomes. Glied and Lleras-Muney (2008) provide an example of the use of instrumental variables to show how a year more of education reduces the probability of dying from cancer as new cancer treatments and drugs are introduced. In another study using a similar approach, Lleras-Muney and Lichtenberg (2002) show how those with more education are more likely to use newer drugs.

Despite the strong correlation between education and health, a number of challenges exist in confirming that a causal link flowing from education to health persists. A number of biases have been identified that could affect studies that attempt to prove the causal relationship from education to health. For example, omitted variable bias in the education-health context suggests that given the strong correlation between the two parameters, there could exist a number of so-called "third variables" that influence the relationship. Suggested omitted variables that are harder to control for include time preference and ability. Another form of bias stems from reverse causality, in which the observed causal relationship linking schooling to health flows from health to schooling. Some examples of this include the fact that healthier people live longer and would theoretically gain more utility from additional schooling or that those who are healthier are more likely to be able to attend school frequently and therefore attain more schooling overall.

The most promising technique for establishing a causal relationship from education to health comes from using the instrumental variables technique. The seminal study using this technique was conducted by Lleras-Muney (2005) in the US by exploiting a quasi-natural experiment where 30 states in the United States underwent an education reform between the years 1914 and 1939 that changed the mandatory number of years of schooling. Lleras-Muney is able to show a statistically significant three to six percent lowering of mortality rate for an additional year of schooling based on the various instrumental variable techniques. However, she acknowledges that the study might have limited explanatory power in a general context because those who are affected by changes in compulsory education have much lower overall education attainment. Studies using similar techniques done in the UK by Clark and Royer (2013) as well as one in Sweden by Meghir (2018) led to the opposite conclusion that increasing compulsory educational attainment did not have a significant effect on health. Ultimately, the literature remains inconclusive as to if a causal relationship can be established from education to health.

Keywords Productive efficiency, allocative efficiency, instrumental variables, health-education gradient, time preference, health capital model, time allocation

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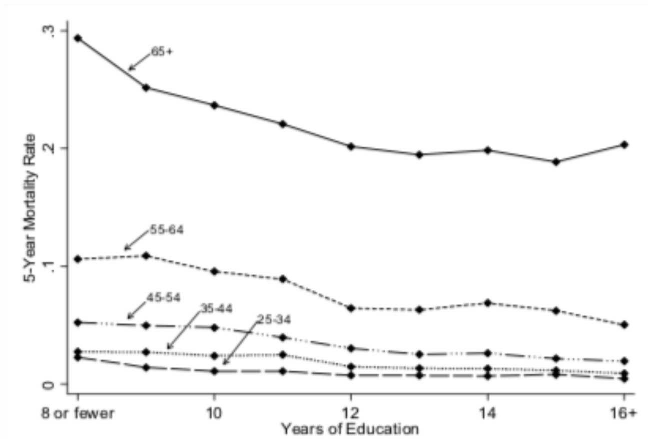
1. Introduction

Ageing population structures throughout Europe have placed increasing burdens on healthcare systems. The proportion of working age people in Europe has decreased and has forced public institutions and healthcare providers to consider new policies and innovations to meet the increased burden from demand for healthcare and other services. For example, the share of the population in Finland that was 65 or older increased by 4.9 percentage points between the years 2008 and 2018 (Eurostat 2019). Also, the proportion of those over 65 has been projected to reach 26 percent of the population by 2030 and 29 percent by 2060 from the current 20 percent (Tilastokeskus 2019). A similar trend exists in the rest of Europe with 19 percent of the population being 65 and over as of 2018 (Eurostat 2019). These trends are a cause for concern as the costs borne by working age people needed to fund existing retirement and healthcare structures will continue to rise. Therefore, a push for innovative solutions as well as investment into preventative healthcare initiatives has emerged to the foreground as institutions attempt to restructure their practices.

A possible mechanism to produce better healthcare outcomes comes through increased investment into education. This has been strongly suggested by the documented relationship between health outcomes and the attained education level of individuals. Starting with Kitagawa and Hauser's 1965 study which links education levels with mortality outcomes, a large number of studies has confirmed the relationship that more educated people live longer. For example, Cutler (2008) computes that for a 25-year-old individual, having some college education leads to an expected 54.4 more years of life, whereas with a high school degree or less, the expected value for remaining years of life was only 51.6 years. In fact, recent studies have shown that this education-health gradient continues to grow in the US. An update from the year 2000 shows that those individuals with some amount of college education are expected to live 7 years longer than those without any college education (Cutler et al 2008). It is noted that this relationship between education and health outcomes holds globally, in both developed and developing nations (de Walque 2007, Cutler et al 2012). These studies, among others, confirm a strong positive correlation between health and education, which has led to a more nuanced look at the causal relationship between health and education.

To expand on the established correlation between education and health as documented by Fuchs (1982) and in several other studies, economists such as Becker (1962) point out that both education and health are critical parts of human capital. In short, the determinants of education overlap strongly with the determinants of health (Clark and Royer 2013). In particular, the positive correlation between health and education has been shown to hold across a variety of contexts including geography, education level, time period in history, gender, and race. Some key studies that explore these relationships include the Williams and Collins (1995) US-based study on race, socio-economic differences and health, the Goldman (2001) survey on the underlying mechanisms that lead to inequalities in health, and the McDonough et al (1999) study on gender and socio-economic factors that lead to a mortality gradient. Each of these studies note the correlations between socio-economic status and health, and then teases out the specific effects of the other factor being studied, such as gender or race. Therefore, a deeper look into the exact nature of schooling and how it has both an effect on both pecuniary and nonpecuniary outcomes for various individuals is warranted.

Figure 2a: Education and Mortality, U.S. Adults over 25, NHIS 1986-1995



Notes: The estimated mortality rates are weighted using the survey weights provided by the NHIS. 5-year mortality is defined as death before the start of the sixth year following the survey year.

Figure 1. Education and Mortality, U.S. Adults over 25, NHIS 1986-1995. There is an observed negative correlation between education levels and mortality rates. Source: Cutler et al (2011)

By establishing a robust link for the causal effect of education on health outcomes, policymakers could be motivated to direct resources towards education-based interventions given the uncertainty of the efficacy of increasing direct healthcare spending (Weinstein and Skinner 2010). However, the types of education goals pursued should be carefully chosen. For example, as shown by Clark and Royer (2013), an additional year of secondary schooling has a minimal causal effect on health, but it is unclear how other forms of education such as college or other levels of higher education would have a causal effect on health.

In the 1960s, economists, starting with Gary Becker, had begun formally exploring the effect of education on nonmarket outcomes such as health. A key theoretical implication that emerged from that period was that health could be viewed as a form of human capital. Some studies on the topic include those by Becker (1964), Mushkin (1962), and Fuchs (1966). In particular, Grossman (1972) identifies the need to specify a unique model for health when applied to the human capital model formulated by Becker (1967) and expanded upon by Ben-Porath (1967), because of the unique insight is that there exists a fundamental difference between health capital and other forms of human capital. Grossman (1972) argues that the stock of knowledge that a person possesses has a direct impact on both market and nonmarket productivity while his health stock determines the length of time that can be used to produce both money and commodities. Another key nuance that Grossman emphasizes is how consumers are looking to buy the commodity "good health" when they purchase medical services. This "health commodity," from Grossman's model, is produced by using the individual's time and an array of market goods and the efficiency of this production is mainly affected by environmental factors, particularly education level.

Empirical studies have shed further light into how the causal relationship of education on health can be evaluated. In the past, economists had used traditional demand theory models to approximate consumer demand for health by measuring the level of medical services demanded (Wagstaff 1986, Erbsland et al 1995). For example, Wagstaff (1995) uses the 1976 Danish Welfare Survey to estimate the unobserved stock of health in individuals by taking the results of a survey that described the individual's relationship to 19 non-chronic conditions. Wagstaff's approach is unique in that good health is modeled as a multidimensional object.

Modern studies have been more precise in determining causal mechanisms by the use of the instrumental variables technique. This was first used by Angrist (1991) to exploit a change in compulsory schooling laws in the US to observe the effect on earnings. The health context was introduced in the quasi-experimental literature study, a widely cited work by Lleras-Muney (2005), in which she exploits US compulsory schooling changes across states as an instrument to examine the effects of schooling on mortality outcomes. Using a similar approach as Lleras-Muney, Clark and Royer (2013) exploit two changes in British compulsory schooling laws reform to produce more robust evidence on the causal effects of education on health. Unique features of the study include the proportion of the population affected by the changes, the selection of a policy change that avoids the weak instruments issue, the ability to identify effects using a regression discontinuity approach, and the ability to examine multiple channels as to how education could affect health. Finally, Meghir (2018) looks at a comprehensive Swedish education reform that was deployed across municipalities in Sweden asynchronously, allowing for a difference-in-difference estimate in addition to a regression discontinuity approach

Among the many challenges faced by researchers examining the causal link between health and education, the use of schooling as an approximate indicator for education has led to some specific considerations that warrant further examination. Oreopoulus and Salvanes (2011) note that education has both pecuniary and nonpecuniary effects on individuals. The pecuniary effects have been well-documented in studies that explore various aspects of labor market behavior and the effects of additional years of high school or university-level education on monetary returns. One particular issue, as noted by Oreopoulus and Salvanes (2011), that arises when studying the non-pecuniary effects of schooling comes from the fact that there is a strong correlation between schooling and other relevant factors like persistence, background, and even genetics that needs to be disentangled in order to form a persuasive argument that isolates the causal effects of schooling. The other issue that arises when studying nonpecuniary effects of schooling is that schooling does generate pecuniary returns (e.g., a higher income) which does have a direct impact on the lives of the individuals. However, Oreopoulus and Salvanes (2011) are able to show a number of significant non-pecuniary effects that arise from additional schooling by conditioning based on income the relationship between schooling and a number of other variables. This leads to the central conclusion that years of schooling and the binary measure of attaining a certain level of higher education degree has less meaning than being able to identify and quantify the relevant skills that come with a meaningful education.

1.1. Research Question and Methodology

This thesis explores the specific relationship between health and education and attempts to provide a comprehensive theoretical and empirical overview of how a causal relationship has been attempted to be established in economics-based literature. While it is widely accepted that there exists a positive correlation between an individual's education and health outcomes due to the various documented relationships and statistical measures, there does not exist the same evidence that would establish a clear causal relationship where education is proven to positively influence health outcomes. These would include the possibility of a reverse causal relationship and the omission of key variables that cause bias in models and empirical studies. Thus, the key questions that this thesis attempts to answer are as follows: *can a causal relationship of education on health be established and what sorts of biases and study design limitations affect the robustness of studies that attempt to show the causal relationship of education on health*?

Research into the relationship between health and education will primarily be based on a survey of various literature from both theoretical and empirical studies on the health-education relationship. The theoretical literature will be evaluated on the strengths and credibility of the key assumptions used to model health, education, and the proposed nature of the relationship between health and education. Empirical literature will be examined based on the quality of the data set, the techniques used to analyze the data sets, and the generalizability of the study.

1.2. Structure of the Thesis

The thesis consists of two main sections. The literature review begins with an overview of the relationship between health and education. Following an examination of theoretical models around health and education, the review then explores the different proposed mechanisms through which education could act upon health. A cornerstone theoretical model of the literature is the Grossman health capital model (1972) which builds off work by Becker (1967) and Ben-Porath (1967). An exploration of this model begins by outlining the model and its various implications for understanding how various investments into education relate to health outcomes. A short literature review follows on works that build off of the seminal Grossman health capital model. I discuss the causal relationship between health and education, the potential for various omitted variables to bias the relationships, and how behavioral-based variables such as time preference affects an individual's health and education. I provide an in-depth analysis of various variables and the mechanisms through which they could influence the health and education relationship.

The second half of the thesis covers a number of empirical studies that attempt to study the relationship between education and health. First, I discuss a number of techniques such as a regression discontinuity design and instrumental variables used to elicit the causal relationship between health and education. I discuss the advantages and limitations of each technique. Then, I explain the design and results from a number of key empirical studies that explore the relationship between health and education and attempt to elicit a causal relationship. Key empirical studies covered include a number of studies from around the world that take advantage of mandatory school attendance reform that change the age at which students were allowed to drop out of compulsory studies. I will explain and compare the various models used in each study to form overall insights on how education and health seem to be related. I will examine some of the biases that could complicate the interpretations and the validity of the studies that attempt to glean insight into the exact nature of the health-education relationship.

Finally, I will conclude with a synthesis of the insights gained from both the theoretical and empirical approaches to describing the structure and nuances of the relationships governing health and education. There will be a discussion about the limitations of current techniques and data collected and what further insight could be derived from a more nuanced view of how humans choose to invest in health and education using frameworks from psychology and other behavioral social science-based disciplines.

1.3. Key Definitions

Human Capital. Economics professor Claudia Goldin (2016) draws on a various number of sources to compile a working definition of human capital. Goldin quotes from the *Oxford English Dictionary* that human capital is "the skills the labor force possesses and is regarded as a resource or asset." There exists the notion that human capital represents investments in persons which include education and health, and also include a range of various traits, skills, and abilities that improve their productivity. From a historical perspective, the notion of human capital existed since Adam Smith. Goldin notes that in Smith's fourth definition of capital, Smith states "The acquisition of such talents, by the maintenance of the acquirer during his education, study, or apprenticeship, always costs a real expense, which is a capital fixed and realized, as it were, in his person. Those talents, as they make a part of his fortune, so do they likewise that of the society to which he belongs." In the 1950s, the term "human capital" increased in popularity and rapidly expanded in interest as a point of interest for research. For example, Becker (1962) identifies human capital as the "imbedding of resources in people" that affect both their present and future well-being. Becker enumerates the various methods of investing in human capital — these include on-the-job training from employers, schooling, and improving mental and physical health. By defining that a person could be invested in for pecuniary returns, metrics were developed to use this concept as an explanatory tool in economic growth theories (see Solow 1956 as an example). In modern times, human capital has extended to include health, with Grossman (1972) playing a large role in developing a health capital model.

Education. The American philosopher John Dewey, a prominent education reformer during the first half of the 20th century, defined education as “the process of the reconstruction of experience, giving it a more socialized value through the medium of increased individual efficiency.” (Dewey 1916). This “reconstruction of experience” includes categories such as beliefs, values, hopes, feelings, and ways of practice. Furthermore, education has an iterative aspect, in which the act of reconstructing experiences adds layers of meaning to it and increases a person’s ability to manipulate further experiences in a desired manner. For the purposes of economics-based literature, education is categorized as a form of investment into human capital. As noted by Grossman (1972), the specific purpose of education is to provide both “allocative and productive returns.” People can produce more in a given amount of time, and they know better which activities to choose to yield higher returns. Given the limited scope afforded by the economic definition of education in comparison to the philosophical approach, education economists such as Oreopoulus note that empirical economic studies that use years of schooling or degree attainment lack the qualitative nuance to determine which aspects of schooling provide both pecuniary and nonpecuniary returns (Oreopoulus et al 2011).

Health. The World Health Organization (WHO) has defined health as “a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity” (Constitution of WHO 1946). From an economics perspective, health is the other pillar of human capital investment besides education. Grossman (1972) notes that earlier economists such as Mushkin (1962), Becker (1964), and Fuchs (1966) had made the theoretical argument that health can be viewed as a form of human capital. However, Grossman made the key argument that health is distinct because it can also set the duration or number of periods in which people are productive. In essence, Grossman has described that health can be viewed as both an investment and consumption commodity. Having better health leads to more utility in the consumption commodity state, and having better health leads to the ability to work longer in the investment commodity state.

Commodities. From the Merriam-Webster online dictionary, the common economics definition of a commodity is a good or service that is fully fungible; forms of the good or service as produced by different groups or individuals are nearly indistinguishable. For the topics presented in the thesis, especially health, a commodity is viewed as something that the individual deems useful that can be broken down into two main components, a time input and a market goods input (Becker 1965). This working definition is used by Grossman (1972) in his conception of health; he notes that the commodity that people look for when purchasing medical services from the market is in fact "good health."

Productive Efficiency. Becker (1965) coins this term to describe the mechanism through which education helps increase the production rate of some non-market goods that produce utility for consumers. Grossman (1972) contextualizes productive efficiency for the health model and suggests education as an example of a mechanism that would increase the efficiency rate at which a person could produce the non-market commodity "health".

Allocative Efficiency. As opposed to productive efficiency, allocative efficiency is an idea described by Grossman (2006) to be an alternative mechanism through which increase in an attribute such as education leads to more utility from a non-market commodity such as health. With allocative efficiency, it is proposed that there is some shift in the individuals' choice of inputs used to create the non-market commodity – in this case, health. For the context of the health-education relationship, this would suggest that the mix of inputs that a more educated individual would use is different from the mix of inputs chosen by a less educated individual.

1.4. Main Findings

An exploration of the literature surrounding the health-education gradient reveal that establishing a robust causal link in the direction of education on health involves addressing a number of challenges including establishing the direction of the relationship, having to use a large array of self-reported health indicators rather than objective biometric indicators of health, and the difficulty in filtering out a number of related "third variables" that include ability bias and time preference.

Putting aside these issues, two main theories stand out as to how education affects health: the productive efficiency approach and the allocative efficiency approach. The productive efficiency approach relies on the premise that education makes individuals and households more efficient at producing health using an array of market and nonmarket goods and services. The other proposed mechanic – the allocative efficiency approach – suggests that the better educated are better able to allocate their resources such as time and market goods to produce health. The literature on the health-education relationship can be grouped into studies that focus on each of the approaches separately and then those that examine the joint approach.

A number of general observations can be made about the empirical literature exploring the education-health relationship. Health is not measured directly in the studies – rather, various proxy measures are used for health, such as mortality or composite subjective measures of health as measured through surveys. Along a similar vein, education is generally not described qualitatively, but rather by a simple measure of years of schooling. Both of these imprecise ways of attempting to measure health and education leave much room for improvement. Inspiration for better measures of education could be found from adjacent disciplines in the social sciences and a better model for health could come from the academic branches of medicine such as epidemiology, where they use quality-adjusted life-years (QALYs) in population health studies to assess disease burden or the value of medical interventions. These more precise measures could yield both better data that leads to more generalizable results.

Furthermore, many of the studies that attempt to prove causation in the direction from education to health have the limitation of relying on quasi-natural experiments with limited ability for generalization. For example, the instrumental variables approach employed by Lleras-Muney (2005) relies on compulsory education reforms done in the United States in 30 different states but those people most affected would be those with low overall education attainment. Given the characteristics of those who attain lower education would be correlated with characteristics such as ability or health, the results obtained in such studies would be unlikely to be generalizable. This is reflected in attempts to conduct similar studies with education reforms using an instrumental variables approach in England by Clark and Royer (2013) and in Sweden by Meghir (2018) that yielded the result that more education did not have a significant effect on mortality (as a proxy for health).

2. Theoretical Framing of Education and Health Relationship

The theoretical relationship between education and health is worth examining due to the intrinsically close relationship between the two objects as the key pillars of human capital. Grossman (2006) contends that these two forms of human capital interact by "affecting the cost and usefulness of each other." There exists an abundance of studies that document this relationship – one organization structure that allows for a systematic survey of the literature involves clustering their relationship contingent on various third variables. For example, the education-health relationship can be grouped as a sub-dimension of the relationship between socioeconomic status and health. Cutler, Lleras-Muney, and Vogl (2011) identify education – along with financial resources, social rank, and rank and ethnicity – as socioeconomic mechanisms that affect health throughout the life cycle. Their work notes that Kitagawa and Hauser (1973) pioneered work using education as the primary indicator to explore the socioeconomic determinants of mortality from a US perspective. Cutler, et al (2011) also highlight the intergenerational dimension of the health and education relationship as one important to explore. Furthermore, studies by Meara (2001) as well as Currie and Moretti (2003) suggest that the educational attainment of parents, especially mothers, impacts the health status of their children. However, despite the variety of correlations linking different elements of health and education documented by these studies among others, none of the studies provide particularly conducive evidence for inferring robust causal links between education and health.

The desire to specify and better understand the nature of a causal relationship between education and health comes from the well-documented correlation between the two variables. Grossman (2000, 2005) notes that the empirical results from various studies show that there is a positive correlation between schooling and health. The three main arguments identified to explain this positive correlation are as follows. In the first instance, it is argued that increases in schooling have a causal impact on health outcomes. In the second set of arguments, the direction of causality is reversed – health has a causal impact on the amount of schooling received. The third set of arguments suggests that the positive correlation between schooling and health arises because of differences in "third variables" in the specified models being studied that are either not identified or are difficult to measure empirically. These third variables which could include physical and mental abilities as well as parental characteristics, are argued to affect health and schooling in the same direction.

This survey of the literature follows the structure of Grossman's (2006) study to organize how various studies attempt to build or expand on theoretical frameworks for how education serves a form of causal mechanism that affects health. While Grossman's (2006) survey provides a more comprehensive overview by surveying studies that examine the effect of education on non-market outcomes in general, the particular contribution of this survey is to delve deeper into the specific relationship of the causal effect of education on health. This survey on these various theoretical frameworks is organized in a parallel fashion to the Grossman (2006) survey – it divides proposals for how education acts as a causal mechanism for non-market commodity production such as health, into two primary categories: effects based on productive efficiency and those based on allocative efficiency.

The concept of productive efficiency is derived from Becker's (1965) seminal theory of time allocation where education increases the efficiency of non-market sector activity. In other terms, Becker identifies education as being a mechanism that increases the efficiency of production of some non-market commodity – more education allows you to do more in the same amount of time. The analogy proposed by Grossman imagines education as technology in a standard macroeconomics growth model where it raises the efficiency of production of some market goods. The other proposed mechanism for a causal link, allocative efficiency, refers to the case where the amount of education an individual possesses causes him or her to change the inputs used to produce a certain commodity. In this education-health context, the allocative efficiency concept has arisen in response to the critique that education cannot have a direct productive efficiency on health – rather, it is suggested that more educated people alter the mix of inputs used to produce health rather than increase their marginal efficiency of health output using the given set of inputs.

2.1. The Productive Efficiency Approach to the Effect of Education on Health

As an introduction to the productive efficiency approach in the health production context, Grossman (2006) goes over three key studies: Becker's (1965) theory of time allocation, Michael's (1972, 1973) studies on the use of various theoretical tools to study the effects of variations in nonmarket efficiency, and his own health capital model (1972), including two later commentaries on the model (2000, 2006). Becker's model looks at how households produce commodities which they want to consume and how this process occurs at different efficiency levels depending on the household members' level of education. Grossman's

(1972) model of health capital draws strongly on Becker's 1965 model and focuses on the production of the specific commodity health. Finally, Michael (1972) provides a framework to empirically test the idea that education can have a productive efficiency effect. Michael (1972) suggests taking cross-sectional data on purchase data for goods and services that lead to a basket that represents total consumption. As an empirical test, Michael collects this cross-sectional data from consumption surveys in order to calculate an income elasticity of demand and a schooling coefficient for each object. This is done by estimating an Engel curve relating expenditures on the item to schooling and income. The theoretical outcome that should be observed is that items with income elasticity of demand greater than one should have a positive schooling coefficient and for items with income elasticity less than one, the schooling coefficient is negative. As Michael states, "holding the household's money income fixed, an increase in its head's education level induces the household to shift the composition of its consumption bundle as if real income has risen." Grossman's interpretation of Michael's work is that the increase in education causes the reallocation of consumption towards luxuries and away from necessities. These models provide the basis for formulating the productive efficiency approach towards explaining the effect of education on health.

2.2. An Overview of Becker's Theory of Time Allocation

Often cited as an economist who applied techniques and perspectives from labor economics-based studies of human capital for non-market-based outcomes, Gary S. Becker makes a number of insightful contributions to how education affects individuals both in the labor market as well as non-market-based contexts. Chiefly, Becker (1965) develops a nuanced approach to understand an individual or household's decision-making regarding time outside of the structured labor market. This leads to a better understanding of how productivity could be affected differently between work and non-work contexts, which leads to different theoretical conclusions about how income and time allocation respond. Later authors on the topic such as Grossman (2006) note the role Becker has in expanding the use of the rational consumer model in exploring variables such as addiction and time preferences that were traditionally under the label of "tastes." Given the large role that education plays in influencing many taste-based variables that are health-linked such as the consumption of addictive substances, investing time into diet and exercise, Becker's various works provide a foundation for how education relates to other non-market goods including health.

Becker's (1965) seminal work *A Theory of the Allocation of Time* applies the standard rational consumer framework to how individuals allocate non-leisure time. In particular, Becker adds the variable of non-working time to the household utility maximization function. Becker defines a commodity as follows: "households combine time and market goods to produce more basic commodities that directly enter their utility functions." In other words, households cannot simply purchase everything they need from the market — time is a necessary input to create objects that households would actually get utility from. Becker provides sleep as an example of a basic commodity — it provides utility by combining the shelter, the bed, with the individual's choice to spend the time to sleep. Grossman (2006) notes that the efficiency of commodity production is often influenced by parameters such as education, and thus is able to define health as a commodity that households would produce when building off Becker's work in his own (1972) health capital model.

Becker's work is significant within the literature because it presents a key departure from standard economic theory – namely that households should be modeled as producers, like factories or other workplaces and not just simply as consumers within the economy. Becker notes that other economists at the time such as Cairncross (1958) also began relaxing the assumption that householders were just consumers and posited that households "[combine] capital goods, raw materials and labour to clean, feed, procreate, and otherwise produce useful commodities". Becker's (1965) model uses the above insight combined with the assumption that given that time can be converted into goods, there is only a single constraint faced by a consumer when trying to maximize utility. To briefly dive into the model, Becker uses the standard consumer utility maximization set-up so that consumers maximize utility functions of the form:

$$U = U(y_1, y_2 \ldots, y_n) \text{ subject to the resource constraint } \sum p_i' y_i = I = W + V \quad (1)$$

The term *I* represents money-based income and is composed of the sum of the prices of goods purchased on the market p_i multiplied by each good y_i. This income is also equal to the sum of earnings that come from work, represented by W, and income that comes from other sources, represented by V.

Then, Becker defines the commodity Z_i that is producible from market goods x_i and time T_i. and represents it as follows:

$$Z_i = f(x_i, t_i) \quad (2)$$

Time (T_i) is noted to be a vector term because time can be separated into various categories such as weekday time or leisure time during the evenings and weekends. The utility function and the resource constraint are placed into the standard consumer utility maximization setup to produce the equation:

$$U = U(Z_i, \ldots, Z_m) \equiv U(f_i, \ldots, f_m) \equiv U(x_i, \ldots, x_m; T_i, \ldots, T_m) \tag{3}$$

subject to a budget constraint: $g(Z_i, \ldots, Z_m) = Z$. The expenditure function g is composed of Z_i, which represents a theoretical upper bound to total resources available to an individual. Z represents a total upper bound on all resources within the system studied. Thus, Becker has created an integrated model that allows the household to both consume and produce.

To facilitate empirical analysis, Becker makes the assumption that the utility function is maximized subject to separate constraints on market goods and time, as well as the production function. The goods constraint is represented by:

$$\sum_1^m p_i x_i = I = V + T_w \bar{w} \tag{4}$$

Becker denotes the vector giving the unit prices of x_i as p_i, T_w as the vector giving the hours spent at work, and $\bar{w}$ as a vector giving the earnings per unit of time spent at work.

The time constraint faced by the individuals is the vector sum of time spent consuming T_c and time spent working T_w, and is represented by the vector T.

$$\sum_1^m T_i = T_c = T - T_w \tag{5}$$

The production functions can thus be represented as

$$T_i \equiv t_i Z_i$$

$$x_i \equiv b_i Z_i \tag{6}$$

The key insight to note that the goods constraint is not independent of the time constraint because individuals shift their time away from "consumption-based" use of time (i.e., leisure) and spend more time at work. Therefore, the combined constraint can be written as follows:

$$\sum p_i x_i + \sum T_i \bar{w} = V + T\bar{w} \tag{7}$$

By substituting the above production functions into to the combined constraint, it can be rewritten as follows:

$$\sum(p_i b_i + t_i \overline{w}) Z_i = V + T\overline{w} \quad (8)$$

$$\text{with } \pi_i \equiv p_i b_i + t_i \underline{w} \text{ and } S' \equiv V + T\underline{w} \quad (9)$$

S' represents the resource constraint and can be interpreted as the money income achievable if all time was devoted towards work. The left side of (8) can be interpreted as the expenditure either directly on goods, $\sum p_i b_i Z_i$ or forgoing income, $\sum t_i \overline{w} Z_i$ for more time available to be spent on consumption. Thus, Becker has shown that the full price of a unit of the commodity $Z_i(\pi_i)$is the sum of the price of market goods and the time used to produce a unit of Z_i. Consuming the commodity requires an input of goods which have a direct price and other inputs which might have some indirect price. The key distinction made here is that there is no analytical difference between the direct and indirect prices that determine total price — as Becker puts it, the direct and indirect price are "symmetrical determinants of total price." This model serves as the foundation for a number of studies that take Grossman's productive efficiency approach into account. In particular, when examining the health-education relationship, Becker's 1965 model provides one sort of explanation for the gap that occurs between health inputs such as medicine and the health outcome. Therefore, it can be argued that education is a key differentiating factor that affects the individual and household production function for health. Education can also enter this model through the change in income that results from education or a different level of access to the selection of goods used to produce health.

A key insight produced by Becker's (1965) analysis of time allocation is that the leisure-labor model specified in classical economics can be seen as a special case of the general time allocation model. To briefly review the neoclassical labor supply model, assuming that leisure is a normal good, when there is a pure rise in income (the income effect is stronger than the substitution effect) the number of hours that individuals supply as labor decreases and when there is a pure rise in earnings (the substitution effect is stronger than the income effect) the number of hours worked increases. In both the basic labor supply model and Becker's time allocation model, these same conclusions can be reached. Another way to look at the relation between the models is to view the labor supply model as a special case of the more general time allocation model in which leisure is viewed as a commodity made up only of foregone earnings and the cost of other commodities is composed only of goods.

2.3. Implications from Becker's Theory of Time Allocation

This theory of the allocation of time as proposed by Becker serves as the foundation for analyses he carries out for various applications of the theoretical model as well as the basis for his later work. For example, Becker notes how the leisure-labor model allows for an explanation of rational household behavior where they set the marginal product of goods and time equal to the marginal costs to produce each other. However, the particular contribution put forth by his 1965 model is that in the case that there is a rise in earnings, there is the explicit recognition that in the case of a rise in earnings, households and individuals would reduce the amount of time and increase the amount of goods used to produce commodities. The example Becker gives to illustrate this point is the phenomenon where individuals—who live in countries such as America with a higher standard of living and productivity—often keep careful track of their time and are very guarded about how they use it, but will haphazardly discard material goods. Specific examples used in Becker's commentary include wealthier communities choosing to use more childcare services and also choosing to pay more in order to be able to book an appointment with a hairdresser rather than waiting in line. The reasoning behind the specific allocative decisions foreshadows interpretations of how education and resources influence better allocative outcomes through individuals becoming more capable of recognizing their specific relationship to time (Grossman 2006). In particular, Grossman identifies that increasing health leads to a greater stock of time that can be allocated to the various investment and consumption decisions that individuals face with their time.

Becker revisits his work on time allocation by modeling how consumers would reduce their discount factor applied to future utilities by linking how various traits such as wealth, mortality, addictions, and other variables affect a person's expressed time preference to varying degrees. Grossman (2006) summarizes Becker's later works as a "series of studies where he applies standard economic models of rational behavior to the problem of analyzing the determinants and consequences of addictions, time preference and other variables that are often viewed as tastes." For example, Becker develops a model to formulate patience, where the discount factor for future pleasure is dependent upon the utility that various individuals perceive from various future-based events (Becker and Mulligan 1997). Becker briefly suggests that schooling and other human capital forming activities have a strong influence on these time preferences, which serves as the basis for looking for mechanisms through which health and education influence each other. Becker and Mulligan (1997) note that a limitation of the model is that there is a static relationship between information and future consumption utility — increased information is positively correlated with future consumption utility and that the rate of discounting remains recursive.

Furthermore, Becker and Murphy (1988) also develop a theory of rational addiction that attempts to explain how addicts behave by expanding on the consumer's time-based utility valuation. The health-related contexts that are included within this study include the consumption of alcohol, cigarettes, and drugs as well as a brief discussion of eating — specifically overeating and dieting. The rational consumer context expands to include preferences that update depending on how past consumption of the good affects the consumer's overall utility. This happens in two ways in the model: a "learning by doing" process increases utility received as the same bundle of goods is chosen while a depreciation rate is built in to account for the value of past consumption of a certain object. The features of the model emphasized by Becker and Murphy include a working definition of "rationality," where "individuals maximize utility consistently over time" and that certain goods become addictive if increases in past consumption of the good raise current consumption of the good. Becker and Murphy acknowledge the limitations of attempting to map all the idiosyncrasies of addiction to a developed model of rational behavior, and instead emphasizes the use of this theory of rational addiction to produce insights and implications on very specific facets of addiction.

Becker's theory of time allocation as well as his later works on related topics such as addiction and time preferences led to a key shift where economists started categorizing these subjects as topics that could be studied through the lens of a rational consumer economic framework. This allowed for later economists to define mechanisms through which education would affect health and vice versa and begin building theories about the causal links between the two concepts.

2.4. Exploring Productive Efficiency Hypothesis through the Grossman Model and its Implications

The significance of Grossman's health capital model comes from its novel treatment of health as a unique form of human capital. His model asserts that health provides individuals with a specific type of utility and the nature of health is different from other commodities that individuals consume for utility. Key differentiating factors of health include the reasons why individuals demand health. First, as a consumption commodity, health provides direct utility. As Grossman (1972) states, "when a person is "sick," which is defined as not having health, they experience disutility. Second, Grossman (1972) interprets health to also act as an investment commodity that determines the total amount of time available to be allocated for working in the market and producing commodities from the nonmarket sector.

Grossman develops a number of unique approaches as to how to treat health as a unique form of human capital within his (1972) health capital model. First, he emphasizes the ability for health to be treated as a unique form of investment commodity with its own mechanisms for maximizing utility. Health is different from other forms of human capital because it increases the number of periods in which a person can be productive, whereas the other forms of human capital merely increase market and nonmarket productivity during the periods in which the individual is productive. As Grossman (1972) states, "a person's stock of knowledge affects both market and nonmarket productivity while his health determines the length of time he can spend producing money earnings and commodities." Second, Grossman takes a novel approach to modeling individual-level health consumption by applying Becker's (1965) definition of a commodity to the healthcare context. Grossman (1972) notes that individuals are trying to buy the commodity "good health" when they purchase the market good "health services." Within the context of Grossman's model, it is noted that these commodities such as good health are considered to be the fundamental objects of choice that enter the utility function rather than some subset of market goods and services. Grossman (2000, 2006) produces a number of commonplace analogies to illustrate the point. For example, in order to produce the commodity "recreation", individuals use sporting equipment and other goods in addition to their own time. Another example follows: to experience the pleasure of a visit to someone, the consumer inputs the cost of transportation as well as their own time. Grossman states that health is demanded for two main reasons. First, as a consumption commodity, people prefer having health to being sick. Second, when viewing health as an investment, it determines the total amount of time available for market and non-market activities. By increasing the stock of health, relatively less time is lost from activities. Assigning a monetary value to this reduction of time lost serves as an index of the return to investments in health.

In addition, Grossman (1972) makes a number of specific decisions as to how to set the intertemporal utility function for individuals. Unlike other models where length of life or the death threshold are set at fixed points, Grossman (1972) assumes that individuals are born with a certain initial stock of health that depreciates over time. Length of life is an endogenous variable dependent on health stock levels that are maximized according to production and resource constraints. In the model, death is represented by the state where health falls below a certain threshold. The model produces the insight that individuals can "choose" their length of life because individuals possess the ability to make gross investments into the health stock. According to Grossman (1972), these investments include the individual's time as well as "market goods such as medical care, diet, exercise, recreation, and housing." Within the model, the health levels for individuals are not exogenous because they depend on the level of resource investment each individual chooses for its production.

Furthermore, the production function for health capital also is affected by "environmental factors." As noted by Michael and Becker (1973), the advantage of a "human capital"-based model is in the ability to take into consideration how consumers spend their time on nonmarket production related activities. Michael and Becker (1973) directly mention Grossman's (1972) contribution on health capital investments being related to expected length of life. The most important factor, according to Michael and Becker (1973) is that by analyzing non-market returns to human capital, environmental factors can properly be considered. In the context of Grossman's (1972) health capital model, Grossman (2006) suggests that as long as the impact of genetic factors can be assumed to only affect how the initial conditions appear, estimates of time paths have no genetic bias and therefore, the actual impact of environmental factors can be teased out. Grossman (2006) notes that a study conducted by Shakotko, Edwards, and Grossman (1981) is able to sufficiently argue the above point by assuming that "the processes governing health and school achievement outcomes are Markov and can be estimated by a simple first-order autoregressive model."

One insight made by Grossman (2000) regarding the significance of the health capital model is in identifying the "shadow price" of health. Staying consistent with the basic laws of demand in economics, the quantity of health demanded should decrease as the shadow price of health increases. Grossman posits that this shadow price does not depend solely on the price of healthcare, but also a wide array of other variables. These variables influence the optimal amount of health demanded. Two key relationships are uncovered by Grossman's (1972) model. First, the shadow price of health increases with age if the rate of depreciation of health stock increases. Second, the shadow price of health would decrease with additional education in the case that "educated people are more efficient producers of health." Finally, Grossman shows that under certain conditions, increases in the shadow price of health can decrease the quantity of health demanded and also increase the quantity of medical care demanded.

In a retrospective survey, Grossman (2000) revisits his original 1972 model and provides responses to critique on two key issues observed by Ried (1996, 1998) as well as Ehlrich and Chuma (1990). The first issue raised is that the 1972 model lacks an optimal length of life condition that is finite and the second issue is that the gap between an individual's initial stock of health and their desired health stock leads to an infinite investment in health followed by no investment if depreciation is eliminated from the model.

To respond to the first point, Grossman (2000) describes an iterative process to determine optimal length of life where utility is maximized over a fixed horizon. In this process, one checks for the stock of health at the end of the horizon and evaluates if it is greater than the threshold that indicates death. In the case that the stock of health is greater than the death stock, Grossman (2000) indicates that the utility should be reevaluated and maximized with respect to a time horizon extended by one period. Grossman (2000) shows that this extended time horizon leads to a diminished supply price of health capital. From mathematical analysis, Grossman (2000) successfully argues that gross investment is larger in the *n* and *n-1* periods and it is the same in all other periods when compared to the case where the horizon gets increased. Therefore, given the case where the depreciation rate of health capital rises with age, life is guaranteed to be finite.

In the other criticism of the health capital model, Elrich and Chuma (1990) decry the assumption that the "technology" used to produce health investment has a constant returns-to-scale because it would lead to a "bang-bang equilibrium." To acknowledge Elrich and Chuma's position, Grossman (2000), points out that the stock of health would be constant over time and that net investment would be zero if the following conditions are met: the rate of depreciation on health stock is zero at all ages, the marginal cost of gross investment in health is not dependent on the amount of investment into health, and none of the exogenous variables are a function of age. Discrepancies between the initial stock of health and the optimal health stock are to be erased in the original period and there is no investment in subsequent periods. This "bang-bang equilibrium" that Elrich and Chuma colorfully describe can be eliminated by assuming that the production function will have diminishing returns to scale as gross investment in health increases. Another way to view this is to note that the marginal cost of investment in health increases as the amount of investment into health increases. Therefore, with the assumption that there are diminishing returns to scale in health investment, individuals are incentivized to reach the desired health stock over time rather than immediately.

Grossman (2000) argues that it is an unnecessary complication to add diminishing returns to scale for health investments. He claims the focus of the health capital model he has created and that other authors, such as Muurinen (1982), have expanded upon does not focus on the predictions implied by the discrepancies that exist between the initial stock and the desired stock of health. Rather, Grossman makes the simplification that individuals reach their desired stock immediately in order to build predictions that can be tested empirically. Grossman also responds to Elrich and Chuma's decision to have the marginal cost of investment in health rise over time independent of investment rate. Grossman argues that because an investment in health at a specific time increases health stock in all future periods and that the marginal product of health falls as health stocks rise, the discounted marginal benefit of investment must fall. Therefore, the slope of the discounted marginal benefit function is negative and an interior equilibrium solution at some period t is possible even if the marginal cost of investment in health were to remain constant.

It is likely that future approaches to the theoretical relationship between health and education will continue to use Grossman's health capital model given its significance and Grossman's ability to respond to later criticism and make necessary modifications or additions to the model. Grossman (2000) suggests that dynamic models that can take advantage of the observation that individuals invest in health throughout life but most invest in formal education only in the beginning parts of their life will yield insight into how an endogenously determined "schooling variable" would help determine if schooling has causal impacts on health through the productive efficiency or time preference mechanisms.

2.4.1. Simplified Grossman Model: A Mathematical Approach

Grossman (2006) simplifies his health capital model (1972) by creating "a pure investment model where health does not enter the utility function directly." Grossman looks to simplify the analysis while retaining the powerful analytic properties of the model. From a production efficiency standpoint, Grossman shows that an increase in schooling predicts that individuals demand a greater quantity of health, but demand fewer medical services.

To study the investment decision for a particular period, the total amount of time allocated to market and nonmarket production (h) is not a fixed value. Grossman assumes that the time allocated is a positive function of health (H) — he argues that by increasing an individual's health, they will lose less time to illness and injury over the course of time. In mathematical terms, Grossman states:

$$\frac{\delta h}{\delta H} \equiv G > 0 \tag{10}$$

Grossman states that health is produced with two main inputs, medical care (M) and the consumer's time (T), with F being linear homogeneous in M and T. By definition, given a certain increase in schooling (S), there will be a proportionate increase in the marginal product of M and T. Grossman represents the relationship as follows:

$$H = e^{\rho HS} F(M, T) \tag{11}$$

Using a standard profit maximization setup, Grossman represents the consumer as wanting to maximize the following equation:

$$Wh - \pi_H H \tag{12}$$

W represents the wage rate and π_H is the marginal cost of producing health. Because health is maximized when the marginal "revenue" of health is equal to the marginal cost of producing health, the first-order condition is:

$$WG = \pi_H \tag{13}$$

The optimal percentage change in the quantity of H caused by a one unit increase in schooling (S) is as follows:

$$\widehat{H} = \varepsilon_H \rho_H \tag{14}$$

The optimal percentage change in the quantity of M caused by a one unit increase in schooling (S) is as follows:

$$\widehat{M} = (\varepsilon_H - 1)\rho_H \text{ where } \epsilon_H \equiv -\frac{G}{HG_H} \tag{15}$$

Grossman argues that health output has a finite upper bound — humans have not achieved immortality—and therefore, $\varepsilon_H < 1$. Thus, the predicted conclusion stated at the beginning of the section is reached, increasing schooling increases health demanded ($\widehat{H}$>0) but lowers the amount of medical care demanded ($\widehat{M}$< 0).

2.5. Allocative Efficiency Approach

The allocative efficiency approach arises as an alternative viewpoint as a critique of the productive efficiency approach. Grossman (2006) cites a number of economists such as Deaton, Rosenzweig, Schultz, Kenkel, Goldman, and Lleras-Muney among others as outlining the theoretical aspects of the allocative approach. Features of this allocative approach include the fact that the health production function is multivariate and requires a wide range of inputs. Some inputs are market goods while others could include time and other non-market goods and services. Also, some of the inputs have a negative effect on health. Therefore, the allocative approach utilizes the joint production approach outlined in Grossman (1972).

The allocative efficiency makes a number of assumptions about how health and education interact. First, it is assumed that with increasing levels of education, individuals have a better understanding about how the health production function truly works. Concrete examples as provided by Grossman include selecting diets that are good for health, avoiding behavior that could be detrimental to health such as smoking, and responding quicker than others to new information about best health practices. Another aspect of the allocative approach worth noting is the importance of taking stock of the current health endowment. While a large health endowment is good for current health levels, it lowers the demand for more inputs with positive marginal products and it might even increase the demand for inputs with negative marginal products. As a plausible hypothetical example, a person in relatively good health would not consume products such as medicine and might be more inclined to imbibe substances such as alcohol.

To delve into why the allocative efficiency hypothesis arose, Grossman directs attention towards criticism in the literature where others are unsatisfied with the vague descriptions of how more education leads to a more productive health production function. Grossman highlights Deaton (2002) who points out the opaqueness of the assumption that education has a direct mechanism that influences health status. Deaton brings up empirical evidence showing that education protects health by citing a study where education is compared against mortality rates from a group of rich countries. Deaton then posits that education can have both direct and indirect roles in improving health. To empirically support his assertion, Deaton refers to a study by Farrell and Fuchs (1982) on cigarette consumption where they uncovered that the relation between cigarette smoking and education levels only arose after it became widely known that smoking carried a large amount of health risks. In this study, Farrell and Fuchs (1982) posit that there exists a number of unidentified “third variables” linking smoking and education and suggest that this mechanism that correlates smoking to schooling would be mirrored in the schooling-health correlation. This alludes to an idea that will be explored and re-examined throughout the literature: what is the exact nature of the relationship between schooling and health – and specifically, what are the causal mechanisms that relate education (and its proximate form, schooling) with a variety of health outcomes.

Grossman (2006) also refers to Rosenzweig and Schultz’s (1982) study on infant health production as an example where the allocative efficiency approach is outlined. Rosenzweig and Schultz examine the household production framework where educational attainment is viewed as an “environmental variable” which affects marginal product of production inputs as in Michael’s (1972) model. The particular contribution made by Rosenzweig and Schultz is to note that parents cannot directly influence the production of child health so much as act upon their perception of how they believe inputs affect outputs. Their insight comes from looking at an infant health production function where they identify that gestational weight has an approximately linear relationship between a range of 1000 grams to 3000 grams and that variation comes primarily from perceived social and economic differences. Their theoretical model to study this phenomenon has the unique feature that taxes or subsidies on any specific health-related input do not necessarily affect health outcomes. In order to know a priori the effects of any price change, the exact nature of the health-production function must be observable.

2.6. Joint Approach – Combining Allocative and Productive Efficiency

Finally, the allocative efficiency approach can be used in conjunction with aspects of an approach focused on productive efficiency in describing the relationship between education and health. For example, Glied and Lleras-Muney (2008) propose that technological innovation could serve as a mediator between health and technology. They cite Nelson and Phelps (1966) who proposed that within the labor market, "the return to education is greater the faster the theoretical level of technology has been advancing." Glied and Lleras-Muney outline four proposed mechanisms for how technological innovation facilitates the relationship between health and education. First, more educated people are better informed about new health innovations and are more likely to understand the benefits and thus, adopt the new technology. They cite de Walque (2004), whose study in Uganda looked at the relationship between AIDS and education over a 10-year period with various information-based interventions. The second mechanism identified by Glied and Lleras-Muney involves more educated people being able to implement beneficial technologies in earlier stages than other people. For example, they describe how certain AIDS drugs required complex dosages and regimes and medication did not circulate among a wider population until the medications became simpler and easier to use. The third mechanism refers to how technology is distributed among medical practice providers. Glied and Lleras-Muney point out how those who are more educated and are of higher socio-economic status are more likely to be successful in searching for high-quality providers that provide access to these relevant new technologies. Finally, they propose that income could be an important mechanism that affects the relationship between education and technology use both directly and indirectly. They briefly speculate that education raises income and this additional income allows the purchase of better healthcare, but they do not go into depth due to the limitations of the data they are using in the particular study. Grossman (2006) briefly summarizes the model developed in a related but older 2003 version of the Glied and Lleras-Muney study. Their version of the health production function is as follows:

$$H = F[M_0 e^{\rho(t-u)}] \tag{16}$$

M_0represents the medical technology available in the market at time 0. $M_0 e^{\rho t}$represents the best technology that exists at the time and $M_0 e^{\rho(t-u)}$represents the technology actually used by the medical professional administering the treatment. Based on the model, Glied and

Lleras-Muney predict the impact of schooling to be greater in magnitude for diseases with more recent advancements.

Finally, Grossman (2006) brings up Goldman and Lakdawalla (2002) as having continued work on the problem by showing that conditional on having the same initial health status, those of higher socioeconomic status and are in general more educated spend more on health. They employ a Cobb-Douglas function to model health investment:

$$h = t^{\phi} m^{1-\phi} \tag{17}$$

where h is health investment, t is time invested, and m is healthcare purchased from the market. Health is a function of health investment, represented as follows:

$$H(h) = h^{\gamma} \tag{18}$$

Therefore, health can be represented as follows:

$$H = m^{\alpha} t^{\beta}, where\ \alpha + \beta < 1 \tag{19}$$

The model by Goldman and Lakdawalla shows that an individual maximizes income as follows:

$$max_{m,t} w m^{\alpha} t^{\beta} - \pi m - wt \tag{20}$$

Using the first order conditions, Goldman and Lakdawalla derive functions for time and market-based health inputs as well as an equilibrium health investment function. In particular, Goldman and Lakdawalla consider absolute disparities in health, represented by $\frac{\delta H}{\delta w}$. This choice allows them to firstly acknowledge the model's inability to produce meaningful general results about relative health disparities as well as argue for the importance of measuring the "size of difference in lifetime well-being across socio-economic groups."

Given the various approaches to interpreting how exactly education affects health, the allocative approach has been an alternative that challenges the tenets of Grossman's (1972) health production model which assumes that education affects productive efficiency. However, it does not mean that the allocative approach and the productive approach to the effects of education on health are mutually exclusive. As noted by Grossman (2006), the above-mentioned studies by Glied and Lleras-Muney (2003) and Goldman and Lakdawalla (2002) are in fact combining aspects of both the productive and allocative approaches.

3. Empirical Framing of Education and Health Relationship

Beyond the theoretical approach that proposes a number of structures for the relationship between education and health, there exist many empirical-based studies that attempt to verify these proposed relationships using strategies such as exploring changes resulting from mandatory school attendance reform and analyzing sibling or twin-based health surveys as well as other surveys that retrospectively look at health surveys on various topics among specific cohorts. Existing literature reviews that explore the empirical literature surrounding the relationship between health and education include ones by Grossman and Kaestner (1997), Grossman (2000), and Grossman (2006). While by no means exhaustive, these reviews provide a general overview into a number of dimensions of the health-education relationship by examining measurements from adults, children, and infants using various estimation techniques and attempting to control for third-variable bias.

A survey of the empirical literature that use the productive approach, the allocative approach, or a combination of the two approaches use various techniques reveal that a number of limitations exist in each approach that prevent developing robust conclusions that prove the existence of a causal relationship that flows between education and health. Many conclusions that are drawn from the studies either rely on models that make critical assumptions about the nature of health and medical care or note that the data needed to make robust causal conclusions is hard to observe. The most promising line of research, according to Grossman (2006) involves assuming schooling is an endogenous variable and using the instrumental variables technique in order to measure the causal effect of schooling on health. By finding instruments that are correlated with schooling but not time preference, the instrumental variables technique allows the researcher to avoid having to distinguish between the direct effects of schooling on health and the indirect effects that come through the time preference effect. Ultimately, the studies suggest that schooling has a causal effect on a number of non-market outcomes but it is important to consider the measurements used to assess the magnitude of effects. It can be argued by Grossman (2006), de Walque (2005), Michael (1972) among others, that the causal outcomes of education are more accurately measured by the nonmarket benefits that generally come with shifts in time preference. Grossman (2006) suggests this interest in being able to better accurately measure changes in time preference and describe its relation to both education and health will be critical in being able to develop frameworks that enable evidence-based, better designed policy interventions.

3.1. Observed Empirical Correlation between Mortality Rate and Education

An established body of literature has confirmed the correlation between health and education to be quite robust across multiple dimensions. Kitagawa and Hauser (1973) conducted the seminal research in the field with their study on 1960s census-related data to measure mortality across a number of socioeconomic gradients including income and education, as well as across a number of background factors including race and geography. Their conclusion stated that there was a negative relationship between education and mortality that held across genders when sorting individuals by education. Further work on the matter continued with Grossman and Kaestner (1997) to establish a strong, positive correlation between general education levels and a reduction in mortality levels in the US as measured during the 1960s through the 1990s.

TABLE 4.1. Educational Attainment, by Race, Selected Years, 1960–90 (percentage of persons aged 25 and older)

Year	All Races	White	Black
	Completed four years of high school or more		
1960	41.0	43.2	20.0
1970	52.4	54.5	31.3
1980	66.6	68.8	51.2
1990	77.6	79.1	66.2
	Completed four years of college or more		
1960	7.8	8.2	3.0
1970	10.8	11.4	4.4
1980	16.4	17.3	8.4
1990	21.4	22.2	11.4

Source: Computed from U.S. Bureau of the Census 1993, table 231.

TABLE 4.2. Infant and Age-Adjusted Mortality Rates, by Race, Selected Years, 1960–90

Year	All Races	White	Black
	Infant mortality rates[a]		
1960	26.0	22.9	44.3
1970	20.0	17.8	32.6
1980	12.6	11.0	21.4
1990	9.2	7.7	17.0
	Age-adjusted death rates[b]		
1960	7.6	7.3	10.7
1970	7.1	6.8	10.4
1980	5.9	5.6	8.4
1990	5.2	4.9	7.9

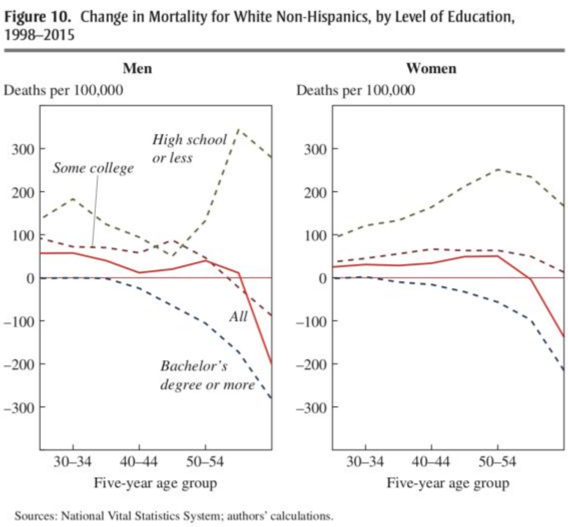
Source: National Center for Health Statistics 1994, tables 1–3 and 2–1.
[a]Deaths of infants under one year old per 1,000 live births.
[b]Deaths per 1,000 population.

Figure 2. Grossman and Kaestner (1997) reproduce data taken from the U.S Bureau of the Census in 1993 and from the National Center for Health Statistics to show that education attainment has increased across races from the 1960s to the 1990s.

3.2. Age-Specific Mortality Shows Unequal Distribution in Health Improvement in U.S.

When zooming in on the education gradient, the literature often labels education, especially in the context of developing countries, as the obtained schooling results of a population. Survey-based studies often use the education attainment obtained by some defined population as a source of variation. In practice, the population is often grouped by levels of education categories such as less than a high school education, completed high school, some university studies, completed four-year university studies, and post-graduate studies. In the economics-based literature, a number of measurable proxies for health are used, with the broadest measure being the mortality rate. According to Case and Deaton (2017), the two most common ways of defining mortality are overall life expectancy and age-specific mortality. Life expectancy at a given age serves as an index measure of life expectancy beyond the given age. In other words, life expectancy at a certain age provides an estimate for the number of years a hypothetical person of the specified age would live if the age-specific mortality rate stayed constant. An unqualified version of life expectancy that does not specify the age defaults to assuming life expectancy at birth. They posit age-specific mortality to be a better indicator of middle-age mortality than life expectancy given that life expectancy is more sensitive to early life changes in mortality rate.

Case and Deaton (2017) serve as representations of development in the survey-based literature on health and education that provides a more nuanced look at trends among certain subpopulations. Their work reveals that despite the larger trend of mortality rates decreasing and education levels increasing in the general population, there are groups that have experienced a reversal of fortunes. They allude to examples where studying middle-age mortality rates is of particular interest in understanding some economic or social changes – specifically, they argue that simply studying the overall life expectancy of a population would not detect changes among the middle-aged cohort. Case and Deaton (2015) provides an example of age-specific mortality rate being the more fruitful object of study in a survey-based context where cohorts were tracked based on education level, race, and gender within the United States. They select age-specific mortality as an indicator to study the mortality rate of white, non-Hispanic people in the United States through 2015 finding that mortality has risen for the white, non-Hispanic population without a college education and that it has fallen for the white, non-Hispanic cohort with a college education.



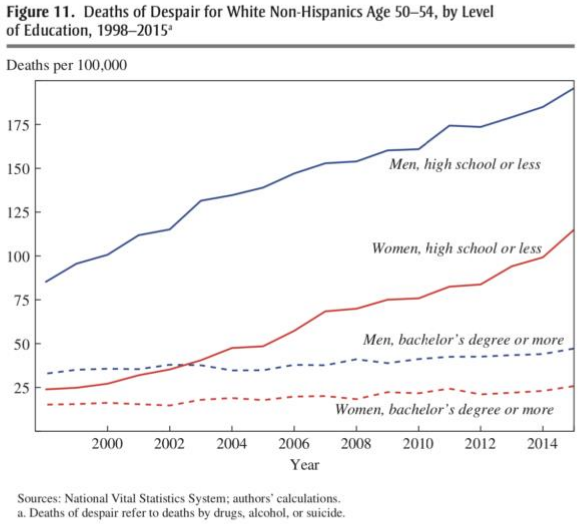


Figure 3. Case and Deaton (2015) illustrate the relationships between mortality and education levels among middle aged individuals, both male and female, in the United States. They highlight the increase in mortality for white non-Hispanic males in their 50s due to deaths of despair over the period 1998-2015.

As background context, Case and Deaton note (2015) that in a representative developed country such as the United States, mortality and morbidity rates between the time period of 1970 to 2013 have dropped for those aged 45-54 by 44%. Cutler (2015) provides a detailed look at some examples of factors believed to contribute to this improvement which include behavioral changes in the population, increased usage of preventative services and improved usage and improvement of post-acute treatments. However, Case and Deaton (2015) illustrate the case of a demographic, namely middle-aged, white non-Hispanic males with low levels of education, who have seen an increase in mortality rates of half a percent since 1998. When considering if these effects are somehow localized or generalizable, Case and Deaton (2017) provide comparisons on the basis of race by comparing the case of white, non-Hispanics in the United States against the Hispanic and black, non-Hispanic populations in the United States. They also provide a comparison based on geography by selecting a subset of rich, developed countries – the United Kingdom, Ireland, Canada, Australia, France, Germany, among others. Within the United States, Case and Deaton (2017) note that during the time period from 1999 to 2015 when the mortality rates of black, non-Hispanics between the ages of 45 to 54 decreased by 2.7 percent a year. During that same period, the mortality rate of the Hispanic population decreased by 1.9 percent annually. In addition, the average mortality decrease observed in the populations of the comparison countries listed in the study was about 2 percent per year. Thus, Case and Deaton (2017) are able to point to a group in

America, namely middle-aged white males, which experienced declining health that was not obvious from the general surveys presented in Kitagawa and Hauser (1973) and Grossman and Kaestner (1997).

3.3. Widening Gap in Health Outcomes between Most- and Least-Educated Cohorts

Other literature that presents a similar story includes a study by Meara, Seth Richards, and David Cutler (2008) which illustrates how gains in life expectancy during the 1981-2000 period happened primarily, if not exclusively among individuals with high education levels (defined as 13 or more years of education). When comparing individuals from 1981-1988 and those from 1991-1998, Meara, Richards, and Cutler (2008) found that life expectancy for those aged 25 had increased by 1.4 years for those with high education levels and only 0.5 years for those with less education. The p-value for this 0.9-year difference between the groups was 0.014, suggesting a statistically significant result. Similarly, from the period 1990-2000, the life expectancy of highly educated 25-year-olds increased 1.6 years compared to an unchanged life expectancy for those less educated. This 1.6-year difference has a p-value of less than 0.001, which is also a statistically significant result. These results were validated from two sets of surveys, one of which included an institutionalized population. Despite the differing population composition of the surveys, they both suggest that the difference in education led to an observed 30% gap in life expectancy.

Case and Deaton (2017) also point to a study done by Olshansky et al. (2012) that expanded the discussion on life expectancy estimates to include race as an explicit dimension in examining how mortality rates vary given educational disparities. Olshansky et al. (2012) describe how life expectancy at birth has increased in disparity between the most and least educated groups from 1990 to 2008 for both genders. They state that in 1990, the differences in life expectancy between the least educated (less than 12 years of education) and the most educated (greater than 16 years of education) were 13.4 years for males and 7.7 years for females. This gap actually increased in the subsequent years – in 2008, the difference in life expectancy had increased to 14.2 years for males and 10.3 years for females. They also zoom in on the "life expectancy at birth" statistic for women by dividing the cohort based on years of education obtained by the age of 25. While life expectancy at birth had increased for every group with 12 or more years of education over the period from 1990 to 2008, there was a consistent decline for the cohort with less than 12 years of education.

It is also important to note that the observations on mortality and education, especially Case and Deaton's (2017) insight on the increase in death of despairs among the white, non-Hispanic population, from the United States cannot be generalizable to other affluent countries. Case and Deaton (2017) show that the all-cause mortality rate for those in the 50-54 age range has increased for the U.S white non-Hispanic population while it has decreased across the board for other U.S. ethnic groups as well as other countries including Ireland, Canada, Sweden, Denmark, and Switzerland among others. One nuance that Case and Deaton (2017) emphasizes is the cause of mortality for the individuals observed in the study. They highlight drugs, alcohol and suicide as being indicative of a "death of despair." They note that these "deaths of despair" had been increasing most in the white, non-Hispanic U.S. population amidst a general increase in "deaths of despair" in other developed countries such as the U.K., Ireland, and Canada. In contrast, the two other largest causes of middle-aged mortality, cancer and heart disease have been decreasing year, with a slowdown in the decrease of the prevalence of heart disease in the population. This can be partially explained due to an increase in the prevalence in diabetes, obesity, and other complications that have increased the incidence of heart disease being recorded in the population (Stokes and Preston 2017). Stokes and Preston (2017) note that the diabetes-related deaths are underreported by a factor of four and show up in death certificates as "heart disease." Thus, the slowdown in heart disease reduction progress could have a link to the rise of obesity and diabetes. In addition, Case and Deaton (2017) explain the main component that led to the slowdown of cancer incidence as lung cancer, which saw a slowdown in the mortality rate decrease among white, non-Hispanic males from ages 45-54 and an increase in the mortality rate among white, non-Hispanic females from ages 45-49. Recalling the various channels through which education could affect health outcomes (as measured through mortality or other proxies), it becomes evident that the causal impact of any intervention or change in education becomes quite complex to disentangle, given the interrelated nature of the existing indices and statistics to measure population health.

Table 2. Average Annual Percent Change in Mortality for Age 50–54 by Cause, 1999–2015

Country or racial or ethnic group	*All-cause*	*Drugs, alcohol, or suicide*	*Heart disease*	*Cancer*
U.S. white non-Hispanics	0.5	5.4	−1.0	−1.1
U.S. black non-Hispanics	−2.3	0.1	−2.7	−2.4
U.S. Hispanics	−1.5	1.0	−2.5	−1.5
United Kingdom	−2.1	1.0	−4.0	−2.3
Ireland	−2.6	3.0	−5.1	−2.3
Canada	−1.1	2.5	−3.0	−1.8
Australia	−1.0	2.5	−2.8	−1.8
France	−1.3	−1.2	−2.9	−1.7
Germany	−1.9	−2.3	−3.5	−2.1
Sweden	−2.1	0.8	−3.1	−2.3
Switzerland	−2.5	−2.6	−4.0	−2.3
Denmark	−1.8	0.1	−4.7	−2.6
Netherlands	−2.3	−0.0	−5.5	−1.4
Spain	−2.1	−0.3	−3.2	−2.0
Italy	−2.1	−2.2	−4.7	−2.0
Japan	−2.2	−2.1	−1.4	−2.8

Sources: National Vital Statistics System; Human Mortality Database; WHO Mortality Database; authors' calculations.

Figure 4. Case and Deaton (2017) provide an overview of middle-aged mortality across different U.S. ethnic and racial groups along with a comparison of select countries to show the relative magnitude of "deaths of despair" in contrast to other leading causes such as heart disease and cancer. There also exists a brief discussion how heart disease as a statistic might be also hiding other causes of mortality such as diabetes and obesity.

Given the extensive surveys and literature examining how education gradients lead to observed mortality differences, there is a clearly documented negative correlation between the two factors. However, these studies that establish correlation between education and health only allude to specific causal mechanisms through which education can affect health. Given the broad definition of both health and education as well as their strongly correlated nature, Grossman (2006) attempts to bring structure to empirical work in the area by dividing a literature review on the subject into effects on child and adult health separately, as well as a grouping based on the specific causal mechanisms as discussed in the theoretical section – productive efficiency and allocative efficiency – through which education affects health. The contribution of this specific paper is to go into detail beyond general literature surveys such as those by Grossman and Kaestner (1997), Grossman (2000), and Grossman (2006). By focusing a subset of studies, the goal of this paper is to provide a framework for evaluating the comprehensiveness and plausibility of studies that attempt to elucidate the mainstream proposed causal mechanisms through which education influences health outcomes.

3.4. Productive Efficiency Approach in Empirical Models

As discussed in the theoretical section, the productive efficiency hypothesis approach looks to establish the idea that increased education leads to a more productive ability to utilize assets to produce the non-market good health. An empirical treatment of the matter often views health as an investment commodity, a consumption commodity, or some combination of the two types. Most of the literature that attempts to verify this hypothesis empirically tries to create proxy measurements for the unobservable health capital of individuals. These studies look retrospectively at survey-based data sets, control for variables that could be correlated to either health or education, and create a regression using some form of the Grossman health capital model, either in the investment, consumption or hybrid model. Surveys that would have longitudinal data would be able to create a robust causal relationship, but given the privacy concerns and cost of collection, most of the studies that examine this relationship use group level data composed of synthetic cohorts.

3.4.1. Empirical Models Based on the Grossman Health Capital Model

There exist a number of empirical studies that attempt to verify the productive efficiency approach based upon the Grossman health capital model (1972). To briefly return to a theoretical nuance, empirical testing of the health capital model relies on assuming that health is a pure investment commodity, a pure consumption commodity, or is some hybrid of the two. Grossman (2000) focuses on the two pure cases to simplify analysis and compares the implications that arise from using the investment and consumption models of health. Grossman (2000) takes the optimal health investment equation and divides both sides by the marginal cost of gross investment to get the following equation:

$$\gamma_t + a_t = r - \hat{\pi}_{t-1} + \delta_t \qquad (21)$$

γ_t represents the marginal monetary return on an investment in health (in period t) and a_t represents the psychic return on an investment in health. In other words, it is assumed that the total returns to health investment can be broken down into monetary and psychic returns. At equilibrium, this rate of return for investment in health can be thought of as the opportunity cost of health capital and is equal to the sum of real own-rate of interest and depreciation.

It is noted by Grossman (2000) that it is reasonable to make the assumption that investing in knowledge or human capital has a large monetary return compared to any other "psychological" returns. This is supported by the findings from Lazear's (1977) study on the returns to schooling. Lazear (1997) shows that as one goes from 0 years of schooling to 12 years of schooling, an average individual would triple their lifetime earnings. In fact, Lazear's model goes so far as to show that formal schooling is a "bad" given that people don't choose to attain wealth maximizing levels of schooling since school attendance is shown to provide disutility. As described by Grossman (2000), the pure investment model for the health capital model depends on the assumption that time spent healthy does not directly enter an individual's utility function or that the marginal utility of healthy time is zero. In this case, health could be interpreted as being just an investment commodity. Returning to the optimal health investment equation, in the pure investment case, the psychic returns to health investment are assumed to be 0, ($a_t = 0$) and thus, the optimal health equation can be stated in the following form:

$$\gamma_t = r - \hat{\pi}_{t-1} + \delta_t \qquad (22)$$

When interpreting this optimal health equation, it can be shown that there exists an equilibrium stock of health where the supply and demand functions for health would intersect. Furthermore, Grossman (2000) notes that the wage rate and the marginal cost of gross investment do not depend on the stock of health. Therefore, given the assumption that health has diminishing marginal productivity, the marginal efficiency of capital should also be negative.

Some ways this investment model serves as the basis of empirical studies include studying changes in the depreciation rate of the health stock. Grossman (2000) explains how health depreciation rates can be shown to increase with age, but variations in rates across people of the same age could lead to various health investment decisions. Other sources of variation that can be explored by this empirical form of the health capital model include changes in the marginal product of health capital. Grossman (2000) sets the value of the marginal product of health capital as the wage rate (W) times the marginal product of health capital (G) to show the relationship between earnings potential and the value of healthy time. The model shows that a person with a higher wage rate values an increase in healthy time more than a person with a lower wage rate. Grossman also describes that those with higher wages are incentivized to use market goods over their own time in producing commodities that provide utility. While the theoretical section of the Grossman health capital model (1972) discusses some partial effects of wage rate or knowledge capital increases, this empirical model allows for an examination of uniform shifts in wage rates or knowledge capital among people of the same age. This distinction allows for the systematic study about how variations in schooling would affect the demand for health capital across ages.

An alternative to the pure investment model presented by Grossman (2000) is the pure consumption model, which presents two clear differences from the pure investment model. Firstly, the consumption model allows for the analysis of wealth effects whereas the investment model cannot because the investment model assumes that a shift in education is analyzed in the context of fixed monetary wealth. Simply put, wealth effects do not matter. Second, Grossman (2000) points out that in the case that individuals could receive a guaranteed real return on monetary capital, any shifts in education would result in gaps between the cost of capital and the marginal efficiency of a given stock of health or other inputs.

3.4.2. Evidence from Retrospective Surveys

Much of the literature discussed that attempts to verify the productive efficiency approach uses the following technique. For retrospective survey analyses, data on various health indicators are gathered to create an approximate indicator for an unobserved stock of health capital. Some variables are controlled for in the population – generally relating to age, wealth, income, and other factors that could be closely correlated to education or health. A select group of literature identified by Grossman (2006) provides evidence in favor of the validity of the productive efficiency hypothesis.

For example, Wagstaff (1986) takes the Grossman (1976) model and fits data from the 1976 Danish Health Survey to reinforce the conclusion that the productive efficiency approach is plausible. Wagstaff (1986) notes how he makes no modifications to the Grossman health capital model in his theoretical framing of the problem. Furthermore, he states that the empirical form of the problem follows the pure consumption model rather than the pure investment model due to not having the right data to fit the latter model. Wagstaff (1986) notes two key unobservable variables, the health stock H_t and the shadow price of initial assets λ_0 , in the model that could lead to concerns in the estimation. The health stock concern can be addressed by estimating a reduced form demand function for both health and medical care. However, given the lack of robustness of the coefficients from the reduced form demand function, Wagstaff suggests to estimate the model's structural parameters. To overcome the unobservability of the marginal utility of the initial stock of wealth despite not having access to panel data, Wagstaff (1986) created estimates by specifying an equation for the marginal utility of initial wealth and estimating any missing wage and asset data for any periods outside available cross-section data and fitting regression equations.

Wagstaff's study of the Danish system contains unique insights in controlling for things such as the cost of care. This occurs because the welfare system in Denmark makes it so that the biggest cost borne by individuals in utilizing medical care is in the time to travel to appointments, rather than the cost of the appointment. Therefore, when viewed through the lens of Grossman's (1976) health capital model, the share of total costs that is monetary can be assumed to be zero. Also, Wagstaff is able to take the indicators from the survey related to non-chronic conditions and create four aggregate health indicators (mobility, mental, respiratory, and pain) that are linear combinations of the original indicators in the survey to create estimates of the unobserved health stock. This addresses the issue of observing the initial health stock. Wagstaff concludes that education does in fact have a positive and statistically significant effect on health in the pure consumption model and it also has a negative and statistically significant effect on the number of visits to a general practitioner. It is noted by both Wagstaff (1986) and Grossman (2006) that this negative coefficient for the number of visits is a contradiction to the empirical results obtained in Grossman (1972), in which the coefficient was shown to be positive albeit statistically insignificant.

Other papers that take a similar approach to Wagstaff and Grossman include a study by Erbsland et al (1995) on the 1986 West German socioeconomic panel. Their results also corroborate the findings of Wagstaff (1986) given that the findings suggest that schooling is shown to have a positive and significant coefficient in the model and that in the reduced form demand equation for physician visits, the schooling effect is negative and significant. Finally, Grossman (2006) brings up a study by Gilliskie and Harrison (1998) where they examine the health and health care data from the 1987 National Medical Expenditure Survey (NMES). It is noted that they identify both productive and allocative efficiency mechanisms through which education affects health. Gilliskie and Harrison find that in aggregate across the productive and allocative efficiency approaches, an additional year of schooling results in positive gains in health across genders. For males, an additional year of schooling reduces the chance of excellent health by 3.5% while decreasing the probability of poor health by 19.6%. While the direction of change for the males seems strange in regards to excellent health, the authors note that there is a significant increase in the chance of good health by 6.22%. For females, the study shows that an additional year of education increases the likelihood of excellent health by 27.6% and reduces the chance of poor health by 38.6%. One issue in the study arises from the identification and treatment of the "attitude" based independent variables. As Grossman (2006) points out, these variables may be influenced by the individual's education levels and therefore would be correlated to other health inputs that are not being measured in the study.

These studies, along with other retrospective survey-based approaches generally suggest that higher amounts of schooling leads to better health across gender, race, and geography. Most, if not all of the studies, measure health using a subset of self-rated dimensions rather than an objective set of biometric data where good health could be defined by a range of results depending on the demographics of the population studied. The proposed alternative methodology of getting detailed health data is cost prohibitive and would often run into privacy concerns.

3.5. Allocative Efficiency Approach in Empirical Models

Many of the studies that employ the allocative efficiency approach look at the individual's decision-making process on health-related lifestyle factors. According to Leigh (1983), the most common lifestyle decisions in relation to health involve the decision to smoke, how much exercise one engages in, and the danger levels of the profession one chooses to undertake. Leigh (1983) uses data from the University of Michigan Quality of Employment Survey from 1973 and 1977 to examine the variation in choices among those at least 16 years of age and who were at least employed half time. This survey and other studies such as those by Kenkel (1991) and de Walque (2004) provide support for the allocative efficiency approach but they do not discount the possibilities of omitted third variable bias, which would come from the omission of time preference that affects both education attainment levels and health.

3.5.1. Studies that Explore Allocative Efficiency Hypothesis through Measuring Uptake of New Technologies and Information that Improve Health Outcomes

Other non-survey approaches to studying the effects of the allocative efficiency approach come from studying the uptake of new information or new technologies that improve health. The theoretical rationalization behind this approach is that more educated people should be responding to this new information or technology the quickest and that empirical results should reflect this. Some commonly exploited health information campaigns involve the themes of smoking and the awareness of the sexually transmitted disease HIV/AIDS.

For example, de Walque (2010) looks at how smoking rates declined after the 1950s when knowledge about the harms of smoking began to circulate. He notes that this effect was most prevalent among college graduates. De Walque creates panels on smoking history to try to reduce the effect of time-invariant unobservable variables to isolate the causal effects of smoking in order to infer causal relationships.

Another smoking related study conducted by Farrell and Fuchs (1982) examines the smoking behavior of those interviewed in small agricultural towns in California by the 1979 Stanford Heart Disease Prevention Program. This study explicitly addresses the time preference hypothesis because they take two snapshots of the participants at ages 17 and 24 to make causal inferences about the before and after effects of a widespread information campaign.

The other prominent public health case used by economists to attempt developing a causal framework for the effects of education on health is the HIV/AIDS epidemic. While de Walque (2005) looks at an international case in Uganda where a decades long prevention campaign on the dangers of HIV/AIDS was implemented. Over the decade, de Walque (2005) finds that education has lowered the prevalence of AIDS. In the background, he also describes a positive relationship between education and condom use. Regardless of the permanence of the relationship between AIDS and education, de Walque notes that some causal relationship between education and health (AIDS reduction) exists. Grossman (2006) posits that a weakening relationship over time supports the allocative efficiency hypothesis while a persistent relationship would suggest either there are unidentified third variables not being measured or that the productive efficiency hypothesis holds.

Another context where the allocative efficiency hypothesis has been tested is in the relationship between education and the uptake of new medical technologies that would improve health outcomes. For example, Glied and Lleras-Muney (2008) use the Surveillance Epidemiology and End Result (SEER) Cancer Incidence Public Use Database to examine how progress in cancer drugs, treatments and other technology has affected mortality rates of different cancers. Their study notes a negative and significant effect of compulsory schooling on mortality rates for both males and females. According to Glied and Lleras-Muney's study, the effect of education on cancer mortality conditional on diagnosis using the two-sample instrumental variables estimate is -0.06. Given that the effect of one more year of education on the probability of dying at the mean is calculated to be 0.634, at the mean, it is suggested that one more year of education reduces the chance of dying of cancer within five years of diagnosis by 10 percent (calculated by division of -0.06/0.634). Also, they note that the negative relationship between education and mortality is greatest in the cases where the cancer progresses rapidly and it is presumed that the treatment routines become more complex to manage in such instances. In a more general context, a different study by Lleras-Muney and Lichtenberg (2002) suggests that more educated individuals are more likely to try a recently approved drug from the United States Federal Drug Administration. The basic result is that an additional year of schooling leads to being willing to use drugs that are 0.16 years younger. This result, as noted by the authors, is statistically significant at the one percent level but in the context of the average drug development cycle being 25 years, this value is not very large. Their study notes that the drug prices faced by individuals of different socioeconomic means do not necessarily affect their general access to drugs. Rather, in the American context, access to insurance and the coverage offered by each type of plan does cause variation in behavior and this is controlled for in the study. Also, Lleras-Muney and Lichtenberg (2002) note that despite annual income being controlled for, there could exist wealth effects that come from more permanent factors that cannot be detected by annual income measures. They refer to a study by Meer et al (2001) where they used instrumental variables to show that the effect of wealth on health not being causal to justify the limitation of their study not being serious. In their discussion, they acknowledge that there are limitations to definitively asserting the causal effect of education on consuming newer drugs. Like with the other education-health contexts, biases that might affect the power of the study to attribute a causal relationship between the education and the health concept of taking the new drugs. These would include omitted variable bias (especially with regards to ability), and a reverse causal relationship where those who fail to use the new technology are sicker on average and fail to attain a high level of education. In order to minimize the disruption of these biases, a suitable instrument for the instrumental variables technique would be required, but the authors noted that there was not a suitable one available.

3.6. Biases that Affect the Causal Relationship between Education and Health

Criticism in response to the frameworks used to study the causal relationship of schooling on health largely revolves around the idea that schooling is an endogenous variable in these health-education models. The types of biases that are discussed by Grossman (2006) as well as Card (2001) include reverse causality and omitted "third-variables," especially time preference. However, some solutions to correct the biases exist with various degrees of feasibility for implementation. When creating a regression relating adult health to own schooling, one could include past health measurements. However, the biggest obstacle to successful implementation of this technique usually involves data measurement imprecision and general unavailability. Another possibility is to use twins or close siblings as the objects for observing the difference in outcomes in various studies. As discussed previously in section 3.3.1, there exists the possibility of using the instrumental variables technique to avoid especially omitted third variable bias.

3.6.1. Reverse Causality Bias

Grossman (2006) mentions reverse causality as one of the causes of bias in studies where the goal is to examine the effects of schooling or education on health. The reverse causality bias refers to a mechanism where healthier individuals are more efficient at producing knowledge through formal educational settings such as school. These students are also suggested to miss less school than students prone to illness, which might increase their learning. Another phenomenon of note resulting from the bias comes from the assumption that if past health in fact influences current health, the effects would be long lasting. Finally, if it is assumed that individuals are forward-looking and rational, having a lower mortality would induce individuals to choose less schooling because they would have less periods to reap the rewards from their investment into their education.

To support these observations, a number of empirical studies have developed frameworks to describe how poor childhood health affects later educational outcomes. Pioneers in this space include Edwards and Grossman who look at how intellectual development in children is affected by their health (1979) and later how different family characteristics affect health outcomes for young children between the ages of 6 and 11 (1981). Edwards and Grossman (1979) look at a health survey administered in the 1960s and restrict analysis to white children who live with both biological or adoptive parents. They note that their ordinary least squares approach could have limited causal explanatory power because of the omission of many genetic and environmental factors in the regression. These factors which potentially serve as a large influencer in the observed outcomes, suggest that there could be a causal link that runs from cognitive development leading to better health leading to the conclusion that certain relationships chosen for the study would not have any true effect on health. At that point, Edwards and Grossman (1979) acknowledge that their study could only observe if there was a significant correlation and that without a controlled experiment, causality would be hard to establish. From the study, it is concluded that the specific indicators used to measure early health led to a correlated set of poor outcomes in school achievement and low IQ. However, there is a question of the ability to generalize results given that the population is white and the family conditions chosen for analysis are narrow.

Currie (2000) aggregates studies on child health outcomes in developed countries to cover the lack of attention towards the subject in the United States as well as uncover general factors and suitable identification strategies to study child health. A major difference between how child health studies conducted in developing countries versus developed countries involves the types of data being collected. Developed countries often use more subjective measures such as surveys done by mothers and general utilization rates of care while studies examining outcomes in developing countries have more quantitative measures of objective factors such as birth weight, height, and nutrition intake. Also, Currie (2000) recognizes the non-linear impact of various inputs on child health. When starting nutrition levels are extremely low or access to the doctor is extremely limited, any increase in food quantity and quality or greater access to a doctor makes a large impact. However, given the general access levels to food and care are much higher in developed countries, the effect of changes in input quantities are generally lower. The model for child health developed for the study uncovers a number of insights. First, as the price of identified relevant health inputs for child health increases, the consumption of these inputs decreases. This relationship serves as the basis for further studies on the importance of access. Furthermore, Currie echoes Grossman in discussing the possibility of spending on child health as a form of investment given that child health in the current period is dependent on child health in past periods.

Beyond the two highlighted studies, Grossman (2006) also highlights a number of studies by Shakotko, Edwards and Grossman (1981), Chaikind and Corman (1991), and Case, Fertig, and Paxson (2005), etc. Given the collected evidence for causality in the direction from health to education, it is important to acknowledge possible limitations in studies where there is an attempt to establish a unidirectional relationship from education to health. Grossman (2006) suggests that one possible way to correct for this bias is to include past health measurements when performing regressions relating health to education.

3.6.2. Omitted Third Variable Bias

Another form of bias that has been identified in the literature and extensively debated is the existence of omitted "third variables" that would cause the direction of both schooling and health (in both children and adults) to vary in the same direction. Two identified "third variables" of note in the literature relate to ability bias and time preference. The argument for ability bias is as follows: in the many studies where more schooling is correlated with higher earning, the studies fail to account for their natural ability to be more productive and succeed across various contexts. The other third variable, time preference, was first identified by Fuchs (1982) who categorized people by their value of the future. Individuals that are more future oriented are more likely to attend school for a longer period of time and make larger investments into their own well-being and that of their children.

Ability bias is discussed by Mincer (1974) in his seminal work where the relationship between schooling, experience, and earnings is explored. Of particular note are the comments in the summary interpreting how an observed low level of correlation between investment into human capital and earnings does not necessarily mean that the human capital model has a fundamentally flawed premise. Rather, there is an uncovered relationship between ability and opportunity that affects investment levels and earnings that is related to the structure of the individual supply and demand faced for each person. Only in the cases of equality of opportunity, equality of ability among individuals or perfect correlation between ability and opportunity would the measured correlation between be perfect. Also, Mincer describes how by omitting ability from an earnings function, a specification bias occurs and the resulting observed rate of return would be upwards biased. Mincer then suggests that it is important to be specific in the definition of ability and also how the causal relationships are structured in models that specify an earnings and an ability variable. Mincer provides an example where models that have ability only affect earnings because of its role in human capital investment, then it would be redundant to specify both the ability and human capital variables. The same would hold true if parental education were a variable that would affect earnings only through the human capital investment channel.

The other omitted third variable that is commonly discussed in the literature is that of time preference. This is discussed extensively by Fuchs (1982) in the context of a survey administered to 500 individuals who were asked a series of questions over the phone about time preference as expressed by valuation of money in the present or in the future. Analysis of the results from the consistent answers that revealed time preference shows a weak correlation with years of schooling, smoking and health status. Fuchs' study also highlights the relationship between family and religious background as a determinant of this time preference variable. The two mechanisms through which time preference can affect health are as follows. First, there is the possibility that time preferences are set early in life during childhood and remain stable throughout life. The variation in time preference would then be observed through the decision to obtain a certain number of years of schooling and the level of engagement with health-promoting activities. The other possibility outlined by Fuchs is one where time preference is directly affected by schooling. The hypothesis is that those with more schooling are willing to invest in things at a lower rate of return compared to individuals with less schooling. While Fuchs' study does not reveal which mechanism(s) time preference acts through, there is the possibility to examine the relationship between schooling and time preference. The survey conducted by Fuchs was able to confirm the a priori hypothesis of a correlation between schooling and time preference but the direction of causality was not established.

While twin or sibling-based studies have been proposed to reduce the bias caused by these omitted third variables, using such techniques introduces a number of issues, especially that of small sample size. Other issues in the literature that object to the use of twins, especially by Bound and Solon (1999), point to measurement errors in studies of twins that increase bias and that the variation in schooling between twins or siblings may be systematic and not random. The more promising solution to reduce the chance of omitted third variable bias is through using the instrumental variable technique. The main challenges are in picking suitable instruments that are not correlated to the offending third variable(s) that are the source of bias.

3.7. Studies that use Instrumental Variables to Address Biases

The most promising technique used to isolate a causal relationship between education and health comes from the instrumental variables technique. Card (2001) describes the general approach of instrumental variables as follows – an instrument exists when an observable covariate that affects education (schooling) choices but is either uncorrelated to or independent of potential bias factors such as ability. For example, a study using the technique would identify a variable that would be correlated to schooling but have no correlation to omitted third variables such as time preference, inherent ability, and genetic traits. Grossman (2006) notes the biggest challenge with this approach is the suitable identification of instruments that have plausible lack of correlation with potential omitted variables. Card (2001) groups studies that use instrumental variables based on those that exploit the institutional features of the schooling system and those that exploit differences in cohorts. Examples of studies that exploit institutional features include the seminal work by Angrist and Krueger (1991) that uses birth quarter within the year as an instrument. They observe that people, specifically American men, born later in the year from the period 1930 to 1959 had slightly lower education attainment traits and conclude that the timing of birth might contribute to this. People are allowed to drop out at a slightly earlier age because of this institutional feature. Given birth timing is most likely independent of taste and ability, this is a suitable variable for an instrumental variable estimate setup. While this study looked at earnings results and not health directly, this study led to the groundwork for other instrumental variable setups where the effects of health on education were more directly studied. Select studies of interest include studies by Lleras-Muney (2005) taking advantage of a change in compulsory schooling laws in the US between 1915 and 1939, Clark and Royer (2013) examining a change in the British schooling system, and Meghir et al (2018) examining the effects of a major Swedish education reform.

3.7.1. IV Study Using Compulsory School Reform in US

Lleras-Muney (2005) looks to establish a causal relationship between education and health, specifically mortality, by taking advantage of a quasi-natural experiment where 30 states in the United States changed their compulsory education requirements between 1914 and 1939. The proposed logic was that if schooling forced certain people to get more schooling than they normally would otherwise, the subset of the population that lived in states with longer compulsory education requirements would be observed to live longer and perhaps even be relatively healthier. Lleras-Muney (2005) uses US census data from 1960, 1970, and 1980 which consists of 1% random samples of the entire population. Because longitudinal data on the individuals could not be tracked, Lleras-Muney creates synthetic cohorts to track the deaths at a group level. The groups are aggregated according to gender, the specific cohort and birth date. This approach is noted to contain some measurement error, with deaths being overestimated half of the time and underestimated the other half of the time. In order to reduce noise from other variables and to get a richer understanding of related factors that could affect education and mortality, Lleras-Muney (2005) gathers information on a number of items including state expenditure on education, the number of school buildings per acre, percentage of foreign-born individuals, percentage of colored peoples, percentage of people in manufacturing or agriculture jobs, and number of doctors per capita. Finally, it is assumed that mobility between states was low during the time period studied, a result verified by Card and Krueger (1992).

Lleras-Muney (2005) starts with a regression discontinuity approach looking at the direct changes of the compulsory education reform. The approach of comparing the cohorts right before and after the change in legislation results in being able to compare a similar cohort, but the issue noted by Lleras-Muney is that the sample is small, weakening its explanatory power. However, given that there is a negative trend recorded in mortality rate when examining the discontinuity for the 41 cases of legislation in which compulsory schooling was increased, there exists some suggestive evidence that the laws did in fact reduce mortality. Lleras-Muney looks at the OLS estimation, a two-stage least squares model using Wald estimators (binary instrument variables), and a mixed two-stage least squares estimate to present her results. Lleras-Muney begins with the weighted least squares approach to get a benchmark result despite it being acknowledged to have many biases. The estimated coefficient on the effect of education is reported as -0.017 and is significant even with the addition of other control variables. Next, turning to the instrumental variables results, Lleras-Muney (2005) reports that the Wald estimate for the effect of education to be -0.037 and significant at the 5 percent level. For the two-stage least squares estimate, Lleras-Muney uses aggregated data separated by gender, state of birth and cohorts to show that the effect of education is -0.051 and is also significant at the 5 percent level. Finally, the mixed two-stage least squares estimate shows that the coefficient of education is -0.061 and is significant at the 5 percent level. All these results can be interpreted in the following way: an additional year of education lowers the mortality rate by approximately 3-6 percentage points according to the various instrumental variables method.

Lleras-Muney notes that the results using IV methods are larger than the standard least squares estimates. Lleras-Muney uses a "Durbin-Wu-Hausman test" which attempts to identify if the IV estimates are statistically different from the OLS results. Because a F-statistic of 0.05 with a p-value of .82 is retrieved from the test, Lleras-Muney concludes that the IV and the OLS results are not statistically different, leading to a more definitive claim that education can be shown to be exogenous in the modeled relationship between education and mortality. Besides the significant empirical result that education does in fact reduce mortality, Lleras-Muney does acknowledge that the quasi-natural experiment setting used has limited ability to create generalized claims because the individuals who would be most affected by the compulsory school setting would generally be attaining low levels of education. Furthermore, it is noted by Lleras-Muney that despite establishing a causal relationship for education on mortality, the exact mechanisms upon which education influences health is unclear. Therefore, making public policy inferences based on the study results would be challenging.

3.7.2. IV Studies Using Compulsory Schooling Reforms Internationally

In a similar approach to Lleras-Muney's 2005 study involving a quasi-natural experiment taking advantage of school reform, Clark and Royer (2013) look at compulsory schooling law changes in the United Kingdom during the years 1947 and 1972. This study provides insight into the education-health relationship because of the context of the data. First, the youth population in Britain was much more affected by the compulsory education reform – about half of the cohorts were affected by the 1947 change and one quarter of the cohorts were affected by the 1972 change. On the other hand, in the Lleras-Muney (2005) study, only five percent of the relevant cohorts were affected in the states where changes were enacted. Also, the nature of the education reforms in the UK were that all students after one specific date had to stay up to a year longer in school, leading to a sharp change where a regression discontinuity analysis could yield fruitful results. Clark and Royer confirm in their analysis that the compulsory education reform did in fact increase the educational attainment. In addition, for the 1947 reform, Clark and Royer are able to establish that the 1947 reform did increase the earnings of the affected men. However, despite the established increase in education and earnings in the 1947 case, Clark and Royer do not find significant mortality impacts between the ages of 45 and 69. For men, the 1947 reform led to a 1.1 percent increase in the likelihood of dying between 1970 and 2007. For women, the increase in the likelihood of dying was 0.4 percent. The positive results are attributed to a type I error or increased alcoholism or vice-based consumption based on the additional earnings. However, it is noted that the 1947 cohort is unique in the context that the population experienced the system-wide shocks of the Great Depression as well as World War II. In the case of the 1972 reform, Clark and Royer only found small impacts on mortality between the ages of 20 and 44. For men, there is a general small positive impact on mortality and for females, there is no impact. Overall, Clark and Royer conclude that there are few or no mortality changes from the 1972 reform.

In contrast to the Lleras-Muney (2005) study, Clark and Royer (2013) conclude that from the instrumental variables estimates, one cannot assert a strong persistent effect of education on health. Clark and Royer note that the differences between results between the two studies could be due to a number of factors, including the more binding nature of the school reform in the UK, the UK reform affecting only school attendance and not related factors such as child labor laws, and finally, that the UK reform happened at a national level, whereas the diff-in-diff approach used by Lleras-Muney to exploit differences between states in the United States might capture state-specific trends. The conclusion reached by Clark and Royer (2013) is that they cannot reject the null hypothesis that extra schooling has no impact on later life.

Finally, Meghir (2018) explores a case in Sweden where a comprehensive school reform was introduced in phases during the period 1949 to 1962 where the number of mandatory years of school increased from 7 or 8 years depending on the municipality to a nationwide mandatory 9-year requirement. Other studies, including those by Meghir and Palme (2005) and Spasojevic (2010) show that the education reform did in fact create an impact on the educational attainment levels in Sweden. The data used in analysis covered approximately 1.5 million Swedes born between 1940 and 1957. Because the data came from the national registrar, information about education and school assignment could be linked to certain health outcomes, namely mortality from the Swedish Cause of Death Register, hospitalization from the Swedish Inpatient register, and the use of drugs from the national prescription register. One nuance on mortality that was studied by Meghir (2018) not present in the other works was a stronger understanding about how to differentiate between mortality from different causes. For example, Meghir (2018) notes that circulatory diseases are largely preventable by education and that there are certain categories of deaths classified by epidemiologists as "preventable" or "treatable."

Because the reform occurred in a way that certain municipalities implemented the reform while others had not yet implemented it, Meghir is able to employ a difference-in-difference approach. In addition, Meghir employs a regression discontinuity to exploit the cutoff date for assigning a child to a school year in a similar fashion to the Clark and Royer (2013) study. Meghir first establishes a strong correlation between the education and mortality rate in Sweden using the available data: an additional year of schooling is associated with a 7-percentage point decrease in the mortality rate. The estimated benchmark effect of the reform for the examined cohorts is a 1.6-year increase in lifespan along with an average increase in schooling by 2.4 years. Then, for the regression discontinuity and the difference-in-difference estimates, Meghir (2018) notes that there are no significant effects that would signify a causal relationship for education on mortality. Meghir (2018) pushes the discussion further by looking at hospitalization and use of prescription drugs as other indicators of health, but Meghir reports no apparent effects on any of the dimensions. While the results obtained by Meghir are quite similar to that of Clark and Royer (2013) among others, the study is significant given the size of the data set examined and the multiple dimensions studied including mortality, hospitalization, and use of prescription drugs. Meghir (2018) also notes that Sweden has an advanced healthcare system that does not depend much on financial means to access. Therefore, it is significant that even in the lower end of the socioeconomic scale, Meghir (2018) does not find evidence of a causal relationship.

Given these studies led to various conclusions, with Lleras-Muney (2005) finding evidence of a causal relationship while Clark and Royer (2013) and Meghir (2018) not finding evidence a causal relationship, it becomes important to examine the study design and context in order to draw relevant conclusions for policy or future studies to elucidate the relationship between education and health. All of the authors concur that a stronger understanding of how different channels work in improving health would lead to more insightful studies on how the two dimensions interact. Also, Clark and Royer (2013) speculate that the effects of education on health are heterogenous, with interventions at certain points in the distribution possibly being especially effective.

4. Discussion

The theoretical framing of the education-health relationship according to the specific nature of the mechanisms, productive efficiency and allocative efficiency, provides some color as to a point of contention – how exactly does education cause a certain health outcome. As seen in the literature, regardless of the study design hypothesizing productive efficiency, allocative efficiency, or some hybrid mechanism, the authors are somewhat vague as to how exactly education acts upon health. A number of factors conflate the relationship including the possibilities that there are a number of third variables that link health and education such as income, wealth, and most prominently, time preference.

Grossman (2006) speculates that if time preference is the dominant mechanism that causes education to influence health outcomes, then a public policy approach that takes a more general intervention and incentives future oriented behavior would have the greatest payoff. Specific examples of such interventions could include nutrition and exercise campaigns, given they require a future- oriented perspective from the individual to yield maximum benefit. Furthermore, Grossman (2006) argues that if time preference was the most meaningful mechanism, youth-focused interventions would be of great interest. Grossman (2006) notes that Grossman et al (1993) show that cigarette and other vice-based activities start relatively early in life. However, it can be noted that it is rather unclear how time preference operates on health and education and how its determinants are constructed.

The most promising technique to reduce the sources of bias has been the instrumental variables technique. As discussed in section 3.3.1, many of the studies exploit institutional changes such as education reform or in other cases not discussed deeply within this paper, military drafts. The quasi-experimental studies discussed in this paper – Lleras-Muney (2005), Clark and Royer (2013), and Meghir (2018) – come to differing conclusions about finding a causal relationship between education and mortality. Lleras-Muney reports that education lowers mortality and that this relationship is statistically significant. On the other hand, both Clark and Royer (2013) as well as Meghir (2018) find that they cannot reject the null hypothesis that education does not have a significant effect on mortality. Clark and Royer (2013) contrast their study to Lleras-Muney (2005) by noting that the reforms in the UK were targeted in a way that much more of the population was affected and that the rules were more binding. While this may be true, there also exists the concern that those individuals whose behaviors are changed by a compulsory education reform must have other structural differences from those who voluntarily pursue higher education.

Later studies and commentaries that survey many quasi-experimental studies, including one by Cutler and Lleras-Muney (2007) note that the studies have an overreliance on using the quantity of education as the source of variation rather than quality or content. The authors of the studies also fail to provide adequate explanations or hypotheses about the exact causal mechanisms on which education and health influence each other. To briefly delve into some of the more empirical-based critique, the use of the instrumental variable technique results in a measurement corresponding to the local average treatment effect – external validity may be lacking and the results obtained from the niche population may not reflect what would occur across the larger population. This is most evident in Lleras-Muney (2005), where the education reforms were not strongly binding and only affected a small percentage of the population. Some of these issues are better addressed by Clark and Royer (2013) and Meghir (2018) given the large sample sizes of their studies and the relative extent to which the reform affected the population. Of course, in the case of Clark and Royer's study, two systemwide shocks of World War II and the Great Depression reduced the generalizability of how the education reforms affected both education outcomes and other outcomes such as health.

Thus, when it comes to public policy guidance in regards to education reform, it is still largely unclear whether a general increase in the number of years of schooling has a significant impact on the health of the overall population. This idea should cause policymakers to contemplate arguments for increasing the number of years of mandatory schooling in order to improve population health with more skepticism. Of course, it is unclear how targeted interventions at certain demographics or subsections of the population would change health outcomes. However, as suggested by Grossman (2006), given that there are clear beneficial nonmarket outcomes of education including health in some sense, it would be important to try to quantify some of these benefits or even try to put some dollar amount estimate to some of these impacts in order to make policy arguments. From the healthcare angle, some attempts at quantifying health impacts of interventions have been made in Finland with the TERVA trial conducted by Patja et al (2012) and its eight-year follow up conducted by Mustonen et al (2019). The savings produced from such interventions, whether from a specific coaching-based module or a more general education program, can be traced to existing institutions such as the healthcare system. Such hybrid approaches between healthcare and economics could be fruitful in understanding how exactly education can be targeted to improve health in an effective and cost-efficient manner.

5. Summary and Conclusion

Both the theoretical and the empirical literature begin with the premise that there exists a well-documented correlation between health and education. Starting with Kitagawa and Hauser's (1965) study that links education with mortality levels, the health-education relationship has been explored across many contexts. One central theoretical model that proposes to capture the health-education relationship is the Grossman health capital model, which uniquely viewed health as a form of human capital. This leads to the formation of the productive efficiency hypothesis as the mechanism through which education affects health. In this view, education causes individuals to be more efficient in producing health with the various inputs needed. As an alternative, the allocative efficiency approach posits that the individuals who are more educated use a different set of inputs than less educated people to create health. Finally, it is possible that a hybrid approach combining the productive and allocative efficiency approaches is possible – the two hypotheses are not mutually exclusive.

Case and Deaton (2017) among others add a much-needed layer of precision to mortality as a measurement of health and shows how there are hidden trends in the mortality rates among different parts of the population. Meara et al (2008) show how the health gains are disproportionately distributed among those who are more educated. These studies suggest that the effects of education on health are non-uniform and that a closer look at demographic and other differences is highly warranted. Much of the economics-based empirical work to elucidate the causal relationship is survey-based reviews that look at different cohorts. Many of them exploit some institutional reform or structural change that allows a suitable instrument to be identified for an instrumental variables estimate along with a regression discontinuity estimate around some cutoff where part of a population is exposed to one treatment and the other part is not affected. Many of the surveys that look from the productive efficiency hypothesis note a positive and statistically significant relationship for education on health. For the allocative efficiency models that use instrumental variables, the results are mixed, with some studies suggesting a negative relationship between education and mortality and others noting that there is not a statistically significant result that would imply causality. It is important to keep in mind that a number of biases may influence the health-education relationship. Some of them could include omitted third variable bias, with leading candidates for third variables including ability and time preference. In addition, there is the possibility of reverse causality, where the relationship runs from health to education. Therefore, the literature concludes that more research into how to measure and describe how education influences non-market outcomes such as health would be needed if a causal relationship is to be posited.

While there exists a large body of literature across the social sciences documenting some strong positive correlation between education and health, it requires a multi-disciplinary approach involving experts from healthcare, epidemiology, psychology, and other social sciences to accurately describe much of the nuance in which education and health interact. While this paper has no means been exhaustive in covering the economics literature on the health-education relationship, one of the important discussion points hoped to be raised is in digging into the black box relationship on how exactly education could cause health. Until further insight can be developed on this, the only definite conclusion that can be reached from the literature is that a health-education correlation exists, but a causal relationship is inconclusive due to the high number of endogenous variables, potential omitted third variables, and an inability to necessarily even define the direction of a causal relationship.

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